THE ENGINEER

MARCH 5, 1954

Fast "Breeder" Power Reactor for Caithness

IN a speech moving the second reading of the Atomic Energy Authority Bill in the House of Commons on Monday last, the Minister of Works, Sir David Eccles, referred to the projected power producing reactor in Scotland. He said that it had been decided to build a big fast "breeder" reactor at Dounreay, in Caithness. That site provided the requirements for such an enterprise—an area of at least some hundreds of acres in open country, near the coast (to facilitate discharge of effluent), with large supplies of fresh water and sea water and with access to a supply of labour and the amenities of community life. In full operation the project was expected to provide employment for about 600 men, of whom about half would be recruited locally. For safety reasons the reactor plant would be housed in a spherical steel shell. In answer to a question, Sir David Eccles said that survey work on the site had gone on already and that the construction work would start as soon as the Ministry of Works could "get under way to the requirements of the Lord President's people who are temporarily in charge."

North of Scotland Hydro-Electric Board

THE North of Scotland Hydro-Electric Board's annual report for 1953 indicates that steady progress was maintained during that year in the development of Highland water power, and in extending rural supplies of electricity. The present state of progress may be summed up by the following figures: by the end of 1953 the installed capacity of hydro-electric plant in operation was almost 400MW, while plant totalling 420MW was under construction, and installations totalling 307MW were in course of promotion or survey. The three corresponding figures for millions of units generated were 950, 1263 and 1094. A suggested figure for the total water power resources of the Highlands is put at 10,000 million units per annum (not all of it economically possible to develop), so in the first ten years of its life the Board has either constructed or reached the "promotion and survey" stage with about a third of the resources of its area. With its steam and diesel power installations taken into account, the Board generated a total of 1333 million units in 1953, an increase of 100 million units over the previous year. Considerable progress was made with distribution schemes in rural districts. As regards the construction of major schemes, fourteen hydro-electric power stations were under construction, and also seventeen dams and contracts were placed for five more dams. Eighteen miles of tunnels were driven during the year—a considerable improvement on previous years' progress. The tunnels at Lawers, Invergarry, Quoich and Ceannacroc were all holed through during the year. The 12ft diameter Ceannacroc tunnel with a length of 14,000ft was driven at an average rate of 1000ft a month.

Institution of Electrical Engineers' Annual Dinner

THE annual dinner of the Institution of Electrical Engineers was held at Grosvenor House, London, on Thursday, February 25th, under the chairmanship of the president of the Institution, Mr. Harold Bishop. After the loyal toast had been honoured, the toast of "The Institution" was proposed by Field Marshal the Earl Alexander of Tunis, who complimented the I.E.E. on achieving a membership of over 38,000, which meant that it had nearly doubled its strength in the last fifteen years. He spoke of the growing importance of electrical engineering in the armed forces and he emphasised the need for manufacturers to keep the "knobs and controls" as simple as possible and to simplify maintenance requirements, so that the drill for operating the weapons and the procedure for keeping them serviceable would not make excessive demands on the skill of the Serviceman. In replying to the toast, Mr. Harold Bishop questioned whether the fighting services had a full appreciation of the educational and practical training levels in electrical engineering which they (the engineers) thought necessary for the efficient operation and maintenance of electrical equipment for defence purposes. Mr. Bishop went on to say that there seemed to be grave dangers of increasing control or guidance of scientific research in the interests of defence; action of this sort might be essential now, but it must interfere seriously not only with industrial research but also with teaching. Speaking of the education and training of young engineers, Mr. Bishop referred to the close collaboration that existed between the three major engineering institutions. He believed that marked progress had been made in the past year and that the plan which had been developed for training young engineers—a modification of the original plan proposed in 1950—would commend itself to all interested parties, and would have a material effect on the supply of fully-trained engineers. The toast of "Our Guests" was proposed by Colonel B. H. Leeson, immediate past-president of the Institution, and the response was made by Lieut.-General Sir Ian Jacob, director-general of the British Broadcasting Corporation.

Future of Woolwich Arsenal

IN November, 1952, the Select Committee on Estimates recommended that immediate consideration should be given to the use of Woolwich Arsenal and its fuller integration with the whole organisation of the Royal Ordnance Factories. Following that recommendation, the Minister of Supply set up an inter-departmental committee of inquiry, under the chairmanship of Sir Donald Perrott, which has examined in detail the activities of Woolwich Arsenal. The plan for reorganising Woolwich Arsenal, which has been evolved as a result of the inquiry, was explained by the Minister of Supply in a written reply last Friday. He said that it had been decided to adopt the plan which contained five main proposals. The first of these proposals, the Minister stated, was the dismantling of the filling factory, the site of which, when cleared, being made available for use by industry or by some public authority. The second proposal was to amalgamate the gun and ammunition factories into a single ordnance factory, which would concentrate upon work suited to the special skill and experience of the Arsenal, particularly experimental and development work. Other proposals concerned the sale of a site of about 100 acres on the south side for use as an industrial estate to accommodate firms which had to leave their present premises but which could not move out of the London area, and making available the remainder of the central area of the Arsenal to the service departments to enable them to bring together their engineering workshops, stores and other facilities. Finally, the Minister stated, the low-lying marshland at the eastern end of the site, which for some years would continue to be required for the storage and transit of explosives, would gradually be raised above river level so that in due course it might be possible to turn it to more valuable uses. The Minister added that every effort would be made to avoid causing hardship to the workpeople at the Arsenal. When the reorganisation was completed it seemed probable that, whilst the number of Government employees would be smaller, the labour force on the Woolwich Arsenal site as a whole, including the trading estate, would in total be larger than at present.

Snowy Mountains Hydro-Electric Development

THE Australian Minister for National Development, Mr. Spooner, recently made an announcement, it is reported, about the cost and progress of the combined hydro-electric and irrigation development schemes in the Australian Alps, generally referred to as the Snowy Mountains scheme. The proposals for this scheme, it may be recalled, were described in some detail in THE ENGINEER of June 10, 1949. Mr. Spooner said that the estimated cost of the scheme was £A422 million, based on the Snowy Mountains Authority's first reliable cost data, obtained from the tenders of large North American, European and Australian contracting organisations for work on the Upper Tumut river. The original estimated cost in 1948 had been £A225 million, he noted, and an estimate made in 1952 had been £A422·5 million. The difference between the 1948 and 1952 figures was accounted for by price increases and by a substantial increase in the firm capacity of the scheme. Of the new estimates, Mr. Spooner said rises in price since 1952 had been offset by reductions in the estimated cost of transformers, switchgear and transmission lines. £A374 million represented the cost of power generation, including central collecting points in the area; the balance was the cost of the transmission system from the collecting points to the load centres. Mr. Spooner said that major works for which tenders had been received, together with a dam which was being constructed for the Authority by the New South Wales Public Works Department, would provide New South Wales with additional generating capacity totalling 80MW by 1958 and 320MW by the end of 1959. In addition, by 1959, they would have a supply of water for irrigation in the Murrumbidgee Valley corresponding to approximately 300,000 acre-feet, increasing in the following two years to 500,000 acre-feet a year.

Safety in Ironfoundries

IN our issue of February 19th we noted the setting up by the Council of Ironfoundry Associations, of a committee to co-ordinate and intensify the efforts being made to keep down the accident rate in ironfoundries. This week, a safety conference, organised by the committee, has been held at Leamington Spa. As well as discussing steps for reducing accidents in ironfoundries, this conference has examined safety practice in the steel and rubber manufacturing industries. At the opening of the conference on Monday, Sir George Barnett, H.M. Chief Inspector of Factories, spoke on the Iron and Steel Foundries Regulations and their relationship to safety, saying that, while the total number of industrial accidents in this country was progressively decreasing, the tendency in foundries over the past three years had been for the number of accidents to rise. It was natural to expect, Sir George continued, that the percentage of accidents through molten metal and other hot or corrosive substances would be considerably higher in foundries than in the rest of industry, but it was not really expected that there would be a considerably higher rate of eye accidents in foundries compared with industry generally. They certainly constituted a class of accident to which very special attention ought to be directed. There was, Sir George observed, no scope for complacency in the ironfounding industry in the matter of accident prevention. If progress was to be made, it was essential that in all foundries there should be established an accident prevention organisation, which was an essential and integral part of the works organisation.

French Locomotive Experiences

By EDWARD H. LIVESAY

(*Continued from page 308, February 26th*)

No. II (PART I)—EXPRESS LOCOMOTIVE NO. 232-U1, S.N.C.F.

SHORTLY before the war, two series of "Hudson" 4–6–4 type locomotives, designated class "R" and "S," were built for service in the Nord Region of the S.N.C.F., each to consist of four engines. The "S" class were to be four-cylinder compounds and the first three of the "R" class three-cylinder simples, but the fourth was to have been fitted with a Ljungstrom turbine. The outbreak of war led to the latter plan being abandoned, the engine being completed, after hostilities ended, as a four-cylinder compound of the same general design as the preceding "S" class machines, but embodying certain modifications considered desirable in the light of experience with its forerunners. This engine was numbered 232-U1 (Fig. 8), its chief features being described in this article; its performance on a heavy train running between Paris and Lille will be the subject of Part 2 of this article.

The chief dimensions of the engine are as follows:—

Cylinders:	
H.p., diameter	17·4in.
L.p., diameter	27·2in
H.p., stroke	28in
L.p., stroke	28in
Ratio h.p. to l.p. cylinders	1 to 2·32
Length of connecting-rods, h.p.	8ft 4in
Length of connecting-rods, l.p.	11ft 11in
Valves:	
(Piston) actuated by Walschaerts gear, conjugated; roller bearings throughout	
Diameter, h.p.	12in
Diameter, l.p.	16·25in
Travel, h.p.	8in
Travel, l.p.	10·8in
Steam pressure, 20 hpz.	290 lb/sq in
Boiler diameter	6ft 1in
Boiler length	16ft 2½in
Centre line above rail	10ft
Wheels, diameter:	
Bogie	3ft 2in
Driving	6ft 6in
Truck	3ft 2in
Heating surface:	
Tubes and flues	1683·0 sq ft
Firebox	247·5 sq ft
Superheater (33 elements)	866·0 sq ft
Total	2796·5 sq ft
Frame, cast steel, thickness	4in
Axles, diameter:	
Bogie	6in
Coupled	10·4in
Truck	6in
Factor of adhesion	3·24
Tractive effort	46,860 lb (compound)

Firebox:	
Inside, length, top	12ft 8in
Inside, length, bottom	10ft
Inside width, top	5ft 3in
Inside, width, bottom	5ft 9in
Grate area	56·6 sq ft
Tubes:	
Length	16ft
Diameter, small	2⅛in
Diameter, large	5⅛in
Springs, number of plates:	
Bogie	Thickness 1in. width 5⅛in
Coupled	Thickness ⅞in, width 4·8in
Truck	Thickness 1in, width 5⅛in
Flexibility per ton, bogie	⅛in
Flexibility per ton, coupled	⅛in
Flexibility per ton, truck	⅛in
All axles fitted with roller bearings; coupled axleboxes "Franklin" automatically adjusting wedges. All wheels (bogie, coupled and truck) braked. Lateral play, bogie and truck, 4in	
Minimum curvature taken	293ft
Weight:	
Bogie	33 tons
Coupled axles	22·5 tons each
Truck	29·5 tons
Total	130 tons
Tender	80 tons
Coal	9·5 tons
Water	7700 gallons
Brake: Westinghouse, direct and automatic	
Coefficient on coupled axles, maximum	160 per cent
Coefficient on coupled axles, normal	85 per cent
Coefficient on bogie and truck	60 per cent
Speed limit	88 m.p.h.

Auxiliaries

One live steam injector.
A.C.F.I. pump and feed water heater.
Air sanding, Nord type.
Electric lighting by turbo-generator.
Two mechanical lubricators, twenty-four deliveries.
"Dalmar" sand tube cleaner.
Two safety valves, 4in.
Mechanical stoker, "Standard" H.T.I. "Hudson" rocking grate.
"Kylchap" double blast pipes, adjustable orifices.
Flaman speed indicator and recorder.
Maximum h.p. 3500.

It is probable that this 4–6–4 express locomotive represents the most advanced design running in Europe to-day, and possibly in the world. In it is embodied all the experience of multi-cylindered engines, both simple and compound, gathered over the years by French locomotive engineers. For half a century locomotives built on the De Glehn system of compounding, utilising four cylinders, have been synonymous with high power developed with the minimum expenditure of fuel and water, and the improvements introduced by Monsieur Chapelon, applied to both new and rebuilt engines, raised efficiency even higher, resulting in performances by several French locomotives so remarkable as almost to verge on the incredible—performances which have probably never been equalled elsewhere. "U1" can be looked upon as the last word in French steam locomotive design; it is well worth study for that reason, and because in the case of these "Hudsons," for which Monsieur de Caso, the former Superintendent of Motive Power, is responsible, the basic de Glehn arrangement of cylinders has been dropped. The position of the h.p. and l.p. cylinders has been reversed, the former being placed inside, instead of outside, as they invariably were by De Glehn; and further, the independence of the two sets of valve gear is also no longer a feature of these "Hudsons"; the inside valves are worked from the outside gear, the travel of the two sets remaining at fixed ratios.

Not only is "U1" the most recent four-cylinder compound to be built in France, but it is the last one that will be built there, as any express locomotive that may be constructed there in the future—in the unlikely event of this taking place—would embody the three-cylinder Smith system of compounding; of this I was assured by more than one official during my recent visit. So far as I am aware, at present the Smith system is only represented by one locomotive, No. 242–AI, a 4–8–4 engine rebuilt from a 4–8–2; it will come into a future article. Another system of compounding exists in France in the shape of No. 160–AI, a six-cylinder engine, 2–12–0, with two h.p. and four l.p. cylinders, which was also developed from an earlier design, a 2–10–0; this, too, will come into a later article. This engine, though satisfactory enough, is not likely to lead to further examples of the type, at any rate in France, if only for reasons of high cost of construction and maintenance—and, of course, because no more steam locomotives are contemplated. It is probable that this cost factor has had much to do with the abandonment of four-cylinder engines—if three can do the work, why use four? In any case, the day of the steam locomotive is approaching its end in France, complete electrification of the whole railway system, powered from a series of dams along the Rhone, being the goal. It is the end of another era.

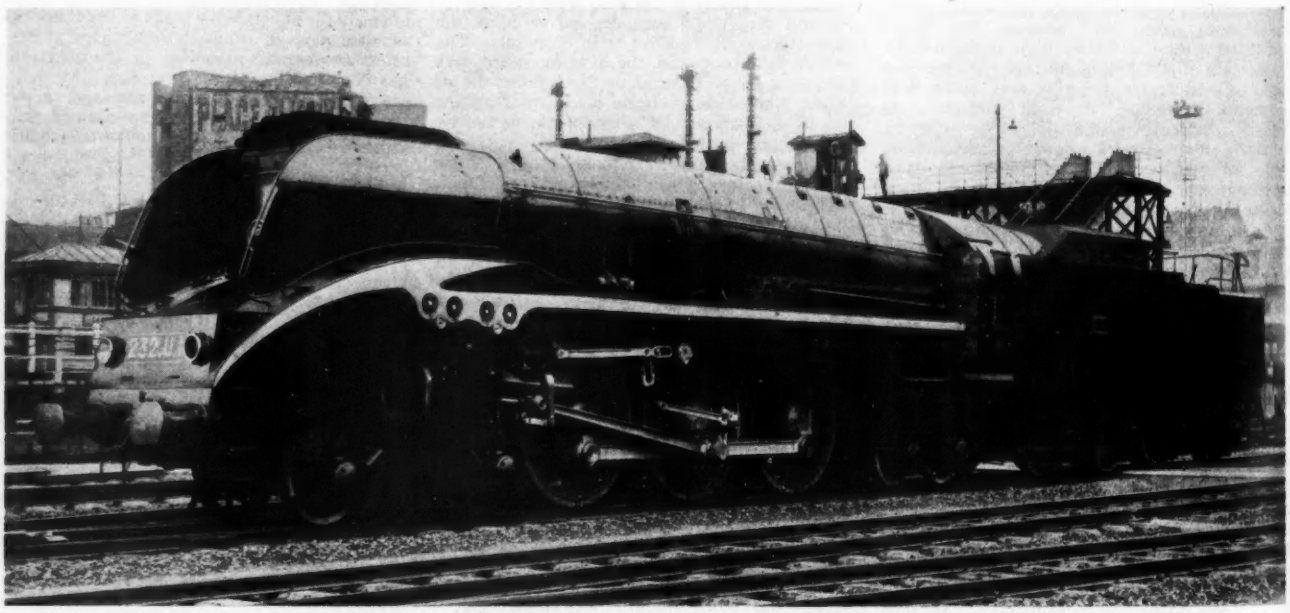

Fig. 8—Four-Cylinder Compound Locomotive No. 232-U1, S.N.C.F.

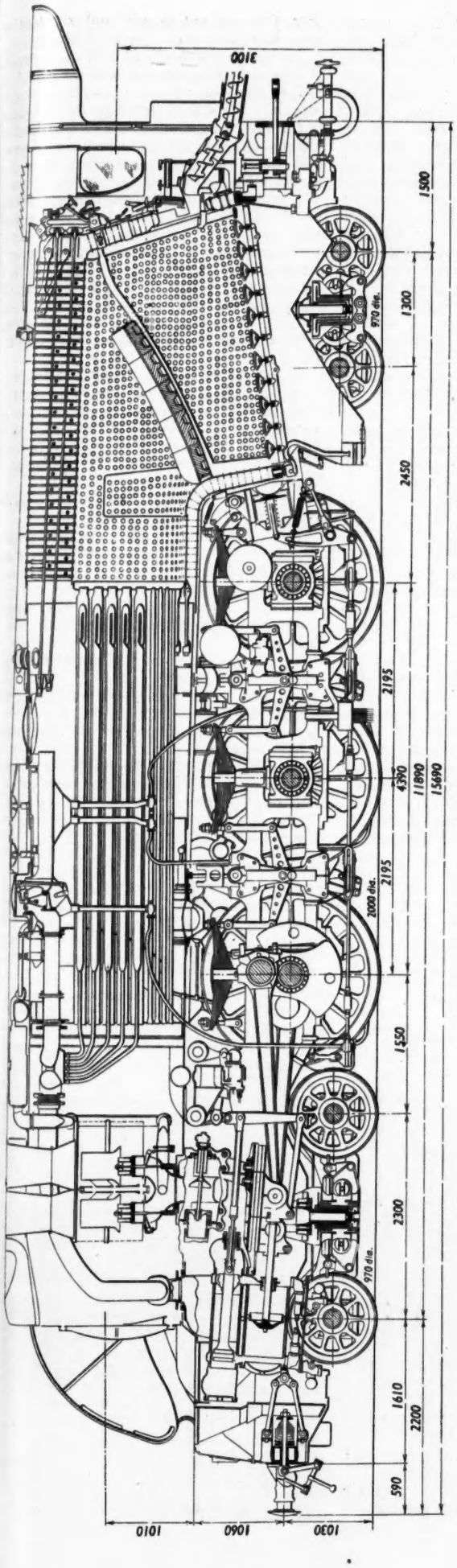

Fig. 9—Four-Cylinder Compound Express Locomotive No. 242-U1, S.N.C.F.

In general, the lines upon which "U1" is built are similar to those of its predecessors of the "R" and "S" classes, but it differs from the other four-cylinder compounds principally in the use of piston valves in place of the "Dabeg"—improved Lentz—poppet valves, cam operated, the system that has been so extensively used on French locomotives; economy of upkeep is the chief reason for the change-over. Roller bearings have been fitted to the driving axles, instead of only to the two trucks as with the "R" and "S" classes. Experience with the preceding engines had shown that the temperature of the combustion gases on reaching the smokebox was too high, so to reduce it the superheater tubes were rearranged in the flues with their axes horizontal instead of vertical, and Houlet elements were substituted for Schmidt. There being no projections, and the lower area of the flues being left clear, there is less tendency for ash and soot to accumulate, and the introduction of a cleaning brush is facilitated.

In the absence of a dome, for which there is no room due to loading gauge limitations, various arrangements were experimented with to prevent the entry of water into the superheater, the difficulty being met by the provision of a dry pipe with a longitudinal slot in the crown, which is expected to work satisfactorily, despite the bad water found in the Lille district. S.K.F. roller bearings are fitted to the driving axles, and Franklin automatically adjusting wedges to the axleboxes; the springs are equalised.

Fig. 10—Layout of Cylinders on Locomotive No. 242-U1

The h.p. cylinders and steam chests (Fig. 10) are cast in one block and have inside admission. The l.p. cylinders, which have outside admission, are cast separately with half-saddles joined on the centre line; combined with them are tubular receivers 10½in in diameter. The l.p. exhaust reaches the blast pipes through the one central orifice seen in the figure.

The h.p. and l.p. valves on each side of the engine (Fig. 12) are worked by the same link, giving the same travel to both. The area of the pipes taking steam from h.p. to l.p. cylinders is kept the same throughout, resulting in easy uninterrupted flow, the ratio, 1 to 2·32, between the two pairs enabling practically the same power to be developed in both pairs. Clearance is 26 per cent in the h.p. cylinders and 17·5 per cent in the l.p.

When the cut-off has a maximum of about 75 per cent, as is usually the case, the difficulty of starting a heavy train is enhanced by this limitation; to overcome this, a special device governed by a servo-motor is found on "U1," which temporarily allows admission during 90 per cent of the stroke of the l.p. cylinders, at the same time bringing the pressure in the high and low-pressure pairs to near the figure reached in normal running,

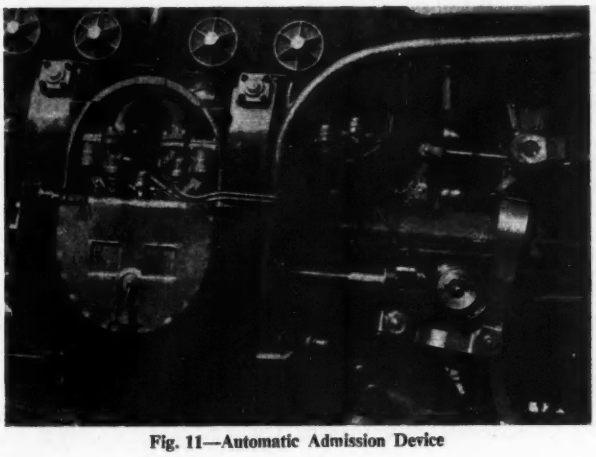

Fig. 11—Automatic Admission Device

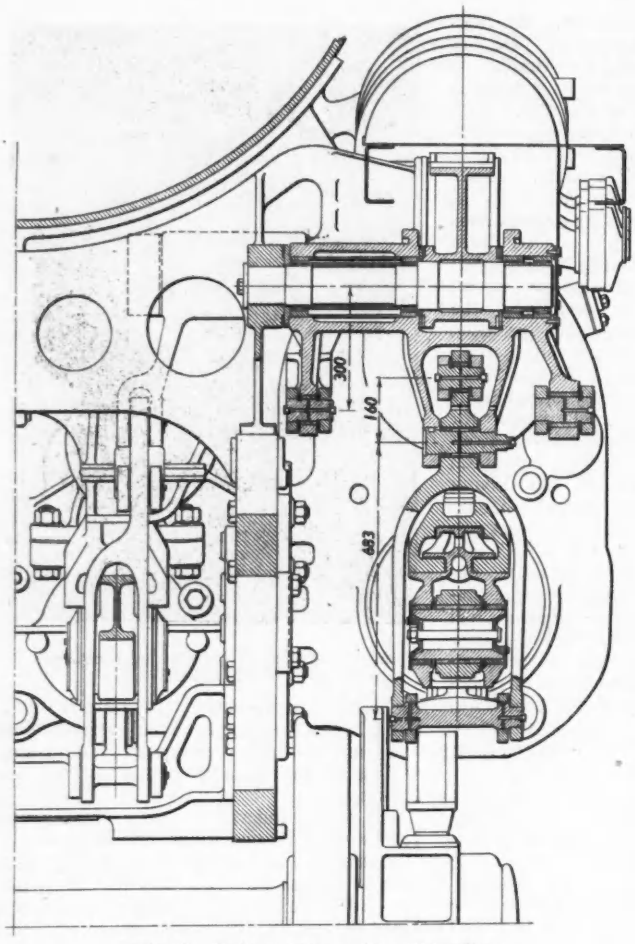

Fig. 12—Conjugated h.p. and l.p. Valve Gear

i.e. 261 lb and 72 lb respectively. Under these conditions, of course, the engine works simple, the h.p. exhaust going straight to the blast pipe. The device comes into automatic operation when the reverse lever is right forward, remaining in action until it is brought back in the usual way as the speed increases to the point giving 55 per cent cut-off, when it automatically ceases to operate ; the cut-off then becomes the same in both pairs of cylinders and the engine works compound.

When I inquired of M. Georges Bohl, of M. Chapelon's staff, whether, bearing in mind the unfavourable angle assumed by crank and connecting-rod as they near dead centre, there was really much advantage in allowing 90 per cent admission, he replied : " So far as the position of cranks and connecting-rods is concerned, you will find that for 90 per cent of the stroke the angle between connecting-rods and the axis of the cylinders is about 33 to 38 per cent, which still gives a torque of six-tenths of the maximum. The lengthening of the admission always improves the starting torque, and reduces the number of positions unsuitable for starting."

The mechanism allowing the two pairs of cylinders to work—as the S.N.C.F. description puts it—in series or parallel—that is to say, compound or simple—comprises two sets of similar but independent devices, one on each side of the engine, worked by air in one direction and steam in the other. They include :

(1) A single-seat intercepting valve in the pipe bringing steam from the h.p. to the l.p. cylinders, opened by steam and shut by compressed air.

(2) A single-seat valve passing the h.p. exhaust direct to the blast pipe when the engine is working simple at starting.

(3) An automatic regulator with a double-seat valve worked by compressed air, putting h.p. and l.p. steam chests into communication. The two regulators (one on each side) act in the same way as the usual auxiliary regulator in the cab admitting h.p. steam to the l.p. cylinders at starting, but are subservient to the main regulator worked by the driver, and also to the reverse lever.

(4) Over each of the l.p. cylinders is placed a device (Fig. 11) which controls the steam admitted at starting giving 90 per cent admission. Each includes a double-seat valve worked by an air piston, opening communication by means of another piston with the l.p. steam chest. At starting these two valves—worked by a cam actuated by the reverse lever—allow the 90 per cent admission already mentioned to the l.p. cylinders.

(5) Four valves (Figs. 8 and 11) over the l.p. valve chest admit air to the l.p. cylinders when the engine is running with the regulator shut, thus preventing grit and combustion gases being drawn in from the blast pipes.

The great advantage of this arrangement is that it enables the engine to be driven in exactly the same way as a simple expansion machine, the driver handling the regulator in the same way as he would on that kind of locomotive. The ease and simplicity of speed and power variation is something quite new in the management of a compound engine. The reverse gear is entirely enclosed, working in oil, and the scale, placed vertically, is very easily read. The distributors, &c., associated with changing over from simple to compound working, and vice versa, are operated by a servo-motor ; everything is automatic, the driver merely altering the valve travel and moving the regulator at his discretion, without being concerned in any way with the other mechanism.

It follows that there are four methods of starting: (1 and 2) simple expansion, with or without the supplementary admission of steam to the l.p. cylinders, and (3 and 4) compound expansion, also with or without supplementary admission. The sequence of events is as follows :—

(1) To get under way, the driver opens the regulator.

(2) Automatically—when the load is considerable and the more complex operation called for—the l.p. regulators open, the h.p. intercepting valves shut, directing the h.p. exhaust to the chimney, and the supplementary 90 per cent admission gear comes into action.

(3) At this stage, the h.p. cut-off is 75 per cent and the l.p. 90 per cent.

(4) The engine being now well away, the engine reduces the h.p. cut-off, but the l.p. admission remains 90 per cent until the former comes back to 55 per cent.

(5) The intercepting valves then open, the h.p. exhaust passing to the l.p. steam chests ; the l.p. regulators shut and the cut-off in both pairs of cylinders equalises at whatever figure the driver chooses.

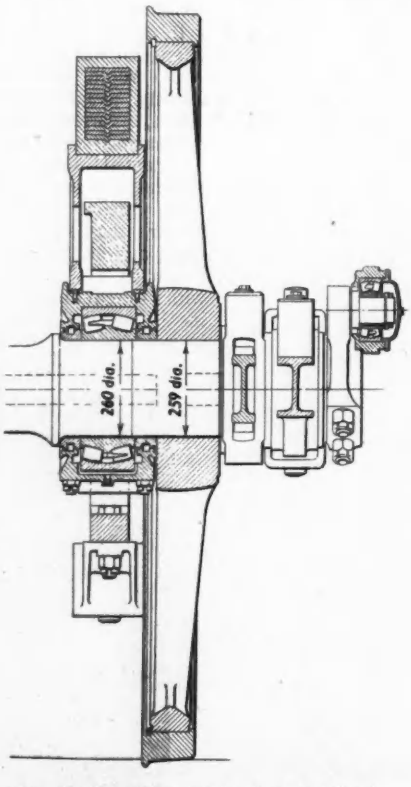

Fig. 13—Second l.p. Driving Axle and Crank Assembly

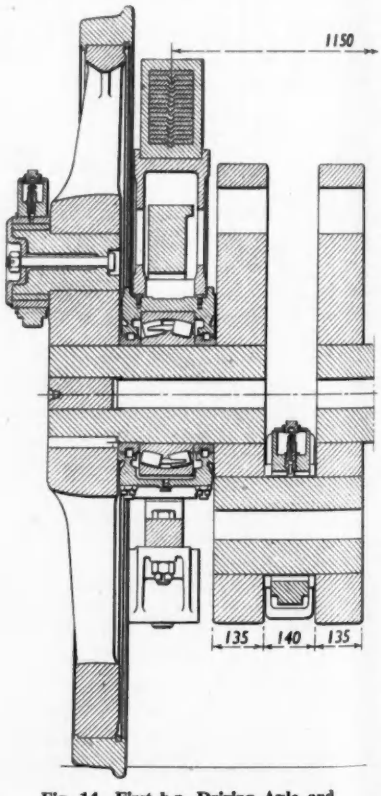

Fig. 14—First h.p. Driving Axle and Crank

(6) The driver then fully opens the regulator, and normal compound working begins.

It is advantageous that steam for cushioning, &c., should be admitted to the cylinders during prolonged running with a shut regulator, as when approaching a stop or on declivities. Under these circumstances, whatever the valve travel may be, when the pressure in the h.p. steam chests falls below 2 hpz. (29 lb), the supplementary distributors open to the atmosphere, admitting air to the cylinders at a corresponding pressure, after which it passes to the blast pipes.

It is stated in the *Revue Générale des Chemins de Fer*, the official organ of the S.N.C.F., that this apparatus is of chief value when associated with heavy trains and steep gradients. It is probable that over easier routes, with loads under 600 tons, this supplementary distribution would not be called for.

The design of the trailing truck is unusual, in the form of a Bissel, but instead of the yoke brought forward and pivoted centrally, it is guided by external parallel arms rocking horizontally.

It will be admitted that " U1 " is an exceedingly interesting machine well worthy of full description. It represents the culmination of the steam locomotive's development in France, and one can only regret that this is not destined to be taken further. There will probably be no successor.

(To be continued)

Second Law Analysis

EDWARD A. BRUGES, B.Sc.*

In this article the author aims to stimulate interest in a method of analysis based on the Second as well as the First Law of Thermodynamics, which, it is claimed, offers a great deal more than the conventional " heat balance." The concepts of available and unavailable energy upon which the analysis depends are discussed and an evaluation of irreversibility is given. The author then illustrates the advantages of the analysis using four worked examples for which a conventional heat account is prepared for comparison.

THE conventional heat account is based on the general principle of the conservation of energy, or First Law of Thermodynamics, and is no more than a tabulated list of energies received and rejected by a system. Such a method of analysis serves to give an overall picture of the performance of the unit concerned, but it cannot examine in detail the losses which occur within the system itself. If the limitations imposed by the Second Law of Thermodynamics are considered, together with the provisions made by the First Law, a more useful analysis may be made than is possible in the usual way. The Second Law analysis is based on the concepts of available and unavailable energy. These ideas are not new and mention of these topics is made by Goodenough,[1] Kiefer and Stuart,[2] Zemansky,[3] and Keenan[4] among others. The physical chemist is familiar with the term free energy which is synonymous with the available energy in certain cases. The change in the Gibbs' free energy corresponds to a change in the available energy under constant pressure and temperature conditions and the change in the Helmholtz free energy corresponds to a change in the available energy under constant volume and temperature conditions. The unavailable energy is the so-called " bound energy." In order that the examples with which the writer deals may be of benefit to the reader it is proposed to consider the implications of the terms mentioned above and define certain properties of a system.†

Availability

Consider the Carnot cycle as represented in Fig. 1. Suppose an engine operating between temperature limits T_1 and T_0, the sink temperature or the temperature of the surroundings receives Q_1 units of heat at T_1 and delivers mechanical work to the surroundings. The maximum amount of work which may be delivered is $(T_1-T_0)/T_1 \cdot Q_1$, a fact which may be established by a corollary of the Second Law. That is to say, due to the reception of Q_1 units of heat by the engine only $(T_1-T_0)/T_1 \cdot Q_1$ equivalent work units are available. Hence, this amount is said to be the available energy (a.e.) and the amount rejected by necessity to the sink is the unavailable energy (u.e.). The unavailable energy is $Q_1-(T_1-T_0)/T_1 \cdot Q_1 = Q_1\ T_0/T_1$.

The above example serves to introduce the concept of available and unavailable energy, but, apart from this, the example is only of theoretical interest since both heat reservoirs

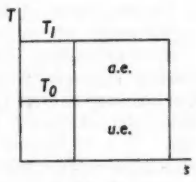

Fig. 1

are presumed to be of indefinitely large capacity. In practice, this is not the case as most problems involve a finite source of heat with the surroundings serving as the sink or lowest available temperature.

(a) *General Change.*—Consider a mass of 1 lb of a fluid to be in a state of rest and to have pressure p_1, volume v_1 and temperature T_1. Let it be assumed that the fluid is contained in an " envelope " which is surrounded by an indefinitely large reservoir exerting a pressure p_0, and having a temperature T_0. In general, T_1 and p_1 will be greater than T_0 and p_0 respectively.

Since the fluid is at a different temperature and pressure from the surroundings it is possible to obtain heat and work from the system until the pressure and temperature of the fluid are equal to p_0 and T_0. The maximum amount of work which may be delivered by the fluid to the surroundings is that quantity given by a reversible engine which brings the fluid from state (1) to that state in equilibrium with the surroundings.

The maximum work is estimated by assuming that the heat given out by the fluid is delivered in an indefinitely large number of steps to a series of Carnot engines working between the temperature of the fluid at any instant as source and the temperature of the surroundings. The work delivered by the engines may be stored in a spring reservoir[7] or work store. Assuming that the fluid has reached a condition where the pressure, volume and temperature are p, v and T respectively, the abstraction of dQ units of heat from the fluid will give $-(T-T_0/T)\ dQ$ units of work from the Carnot engine operating at this temperature level. It is to be noted that dQ is negative when heat is given up by the fluid, whereas $(T-T_0)$ is

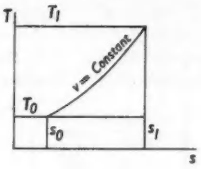

Fig. 2

positive. The opposite is true when heat is absorbed by the fluid. In addition to the work obtained due to the exchange of heat between the fluid and the surroundings work may be obtained if $p>p_0$. Thus, the maximum work obtainable in the small step considered is

$$-(T-T_0/T)dQ+(p-p_0)dv \quad . \quad . \quad . \quad . \quad (1)$$

Integration of equation (1) gives

$$\left[-dQ\right]_1^2+T_0\left[dQ/T\right]_1^2+\int_1^2 p\,dv-\left[p_0\Delta v\right]_1^2 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

or

$$\left[-\Delta Q\right]_1^2+\left[T_0\Delta s\right]_1^2+\int_1^2 pdv-\left[p_0\Delta v\right]_1^2 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

since $\int_1^2 dQ/T=\Delta s$ for the reversible series of steps considered.

Now

$\Delta Q=\Delta E+\Delta W$ by the First Law.

$=\Delta E+\int pdv$ for a reversible change

i.e.

$$-\Delta E=-\Delta Q+\int pdv.$$

The available energy or the availability, to use the word which Keenan adopts, is given by

$$-\left[\Delta E\right]_1^2+\left[T_0\Delta s\right]_1^2-\left[p_0\Delta v\right]_1^2 \quad . \quad . \quad . \quad . \quad (4)$$

or

$$(E_1-T_0s_1+p_0v_1)-(E_0-T_0s_0+p_0v_0) \quad . \quad (5)$$

The difference in availability between any two states x and y of a system, with reference to the surroundings at p_0 and T_0 is given from equation (5) by

$$(E_y-T_0s_y+p_0v_y)-(E_x-T_0s_x+p_0v_x) \quad . \quad (6)$$

The function $(E-T_0s+pv)$ is a function of the state and will be denoted by the symbol b, the availability.

(b) *Change at Constant Volume.* — The availability at the point (1) with reference to T_0 is given by equation (5). Thus

$$b_1=(E_1-T_0s_1)-(E_0-T_0s_0) \quad . \quad . \quad . \quad . \quad (7)$$

or

$$(E_1-E_0)-T_0(s_1-s_0),$$

since $v_1=v_0$.

On inspection it is seen that b_1 represents the triangular area in Fig. 2.

(c) *Change at Constant Pressure.*—Here

$$\begin{aligned} b_1&=(E_1-T_0s_1+p_1v_1)\\ &\quad-(E_0-T_0s_0+p_0v_0)\\ &=(H_1-T_0s_1)-(H_0-T_0s_0) \quad . \quad . \quad . \quad (8)\\ &=(H_1-H_0)-T_0(s_1-s_0), \end{aligned}$$

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† The writer has drawn freely on *Thermodynamics*, by Keenan[4] and on an article[5] by the same author which appeared in *Mechanical Engineering*. The treatment of the subject in *Mechanical Engineering*, which appeared some nine years before the publication of *Thermodynamics*, may not be so thorough as the later version, but it is straightforward and more suitable for the beginner. An earlier article published by Darrieus[6] was possibly the first step towards a Second Law analysis, and Keenan makes reference to this in his own work.

since $p_1=p_0$. As before, b_1 is represented by the triangular area in Fig. 3.

(d) *Steady Flow.*—Consider the case of the steady flow of a fluid from conditions (p_1, v_1, T_1) to conditions (p_2, v_2, T_2) as shown in Fig. 4. In this instance let it be assumed that the kinetic energy of the fluid is small relative to the total energy at sections (1) and (2) and that any potential energy which the fluid may possess by virtue of its height above some datum may be neglected. The availability of each unit mass as it comes to section (1), with respect to the surroundings at p_0, T_0, is increased by the amount of the displacement work or "energy of flow" (pressure work), p_1v_1, less the work which must be expended on the surroundings. This may be made more evident by removing

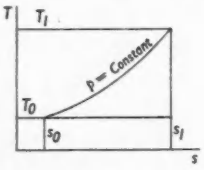


Fig. 3

the unit following section (1), and replacing it with a cylinder and a piston, such that the pressure p_0 acts on the back of the piston. The work which is available for "storage" as each unit mass comes to section (1) is $(p_1-p_0)v_1$. The unit mass may be removed then and allowed to yield its available energy amounting to $\left[E-T_0s+p_0v\right]_0^1$, as given by equation (5).

The availability at section (1) is

$$b_1=\left[E-T_0s+p_0v+(p-p_0)v\right]_0^1$$
$$=\left[E-T_0s+pv\right]_0^1$$
$$=\left[H-T_0s\right]_0^1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where $H=E+pv$.

The change in availability between sections (1) and (2) is

$$b_2-b_1=(H_2-T_0s_2)-(H_1-T_0s_1) \quad . \quad . \quad (10)$$

(e) *Steady Flow: Velocity Included.*—In case (d), if the velocities at the sections are denoted by u_1 and u_2 the kinetic energy amounting to $u^2/2gJ$ is wholly convertible to mechanical work. Before doing work

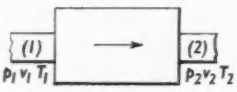


Fig. 4

p_1v_1 in the cylinder already referred to, let the fluid be passed in a reversible manner through a turbine disc, designed so that the fluid emerges with indefinitely small velocity. The work done on the disc at section (1) will be $u_1^2/2gJ$, which may be given to the work store. Thus the change in availability between sections (1) and (2) will be

$$\{b_2+u_2^2/2gJ\}-\{b_1+u_1^2/2gJ\} \quad . \quad (11)$$

extending equation (10) to include the kinetic energy terms.

(f) *Potential Energy.*—In most cases the potential energy of a fluid need not be considered, but for dense fluids such as water the potential energy should be considered.

Evaluation of Irreversibility

Expressing the First Law in the form

$$dQ=dE+p_0dv+dW \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where

dQ=heat added to the system,
dE=increase in the internal energy of the system,
p_0=pressure of the surroundings,
dv=increase in the volume of the system, and
dW=useful work delivered to the surroundings,

one may rewrite the equation, subtract T_0ds from each side to get

$$(dE+p_0dv-T_0ds)=(dQ-T_0ds-dW) \quad . \quad (13)$$

Substitution of the inequality of Clausius, $ds \geq dQ/T$, into equation (13) yields

$$(dE+p_0dv-T_0ds) \gtrless dQ(T-T_0)/T-dW \quad . \quad (14)$$

Equation (14) shows that the increase in availability (L.H.S.) may be equal to or less than $[dQ(T-T_0)/T-dW]$.

Thus the irreversibility in any process is given by

$$\left[\int(T-T)/T \, . \, dQ-W\right]-\Delta[E+p_0v-T_0s]$$
$$. \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Alternative forms for the irreversibility may be used, but there is no need to deal with these here. The irreversibility in any process is measured by the increase in the unavailable energy during that process, which is equivalent to saying that the irreversibility in any process is the amount by which the maximum possible increase in availability exceeds the actual increase in availability—see equation (15). It is proposed to let the examples illustrate the theory given above.

In his text, *Thermodynamics*, Keenan illustrates the advantages of a Second Law analysis with three examples. The examples are (i) a reheating regenerative steam cycle, (ii) an ammonia absorption refrigerator, and (iii) an idealised petrol engine working on the Otto cycle. The writer has chosen the following examples :—(i) a steam power unit with steam reheating ; (ii) a gas turbine plant with two-stage compression, interstage reheating with exhaust regeneration ; (iii) a two-stage ammonia compression refrigerator with precooler, and (iv) a four-stroke cycle compression-ignition engine, working on the Otto cycle, with heat loss to the cylinder walls. Thus the reader who cares to study both sets of problems will have seven different problems covering much of the field of application.

Example 1.—The circuit diagram for a steam power plant is shown in Fig. 5. It

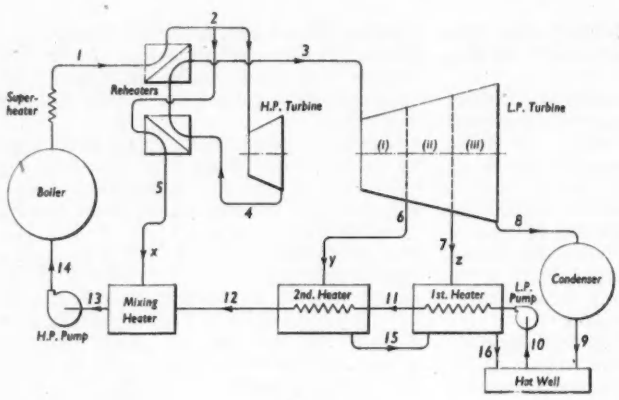


Fig. 5

includes two steam reheaters, direct contact mixing feed heater and two surface feed heaters. Table I lists for the points numbered on the diagram, the condition of the fluid, the enthalpy, the entropy and the availability function b. The function b is given by equation (9) and the properties of the fluid were taken from *Callendar's Unabridged Steam Tables* (1939). The lowest available temperature was taken as 60 deg. Fah. (520 deg. Fah. absolute).

The values of x, y and z per pound of steam leaving the superheater are 0·0966 lb, 0·0913 lb and 0·0865 lb respectively.

Table II.—*Conventional Heat Account*

Energy input	B.Th.U.	Per cent
L.P. pump: negligible	0·0	0·00
H.P. pump: (306·1−301·4)	4·7	0·44
Boiler and superheater: (1360·8−306·1)	1054·7	99·56
	1059·4	100·00
Energy output		
H.P. turbine: 0·9034×87·8	79·3	7·49
L.P. turbine :		
(i) 0·9034×68·9	62·2	5·87
(ii) 0·8121×103·1	83·7	7·90
(iii) 0·7256×170·1	123·4	11·65
Condenser: 0·7256 (1012·4−33·0)	710·6	67·09
	1059·2	100·00

Net work = 348·6−4·7 = 343·9

Overall thermal efficiency = $\frac{343·9}{1054·7}$ = 0·326 or 32·6 per cent.

The limitations of the conventional heat account, of which the items appear in Table II, are evident by comparing this table with Tables III and IV where the items relative

Table III

Availability gain	B.Th.U.	Per cent
L.P. pump: negligible	0	0
H.P. pump: (57·4−52·7)	4·7	0·90
Boiler and superheater: (575·4−57·4)	518·0	99·10
	522·7	100·00
Availability loss		
H.P. turbine : 0·9034 (536·9−426·6)	99·6	19·05
L.P. turbine :		
(i) 0·9034 (498·6−381·4)	105·9	20·26
(ii) 0·8121 (381·4−259·5)	99·0	18·94
(iii) 0·7256 (259·5−34·7)	163·1	31·20
Condenser : 0·7256 (34·7+0·9)	25·8	4·94
Reheaters : 575·4+0·9034×426·6−0·9034 ×536·9−0·9034×498·6−0·0966×184·4	7·6	1·45
Mixing in contact heater : 0·0966×184·4 +0·9034×42·4−52·7	3·4	0·65
Mixing in hot-well : 0·1778×13·5−0·7256 ×0·9−0	1·7	0·33
First feed heater : 0·0865 (259·5−13·5) −0·0913 (46·4−13·5)−0·9034 (15·5−0)	10·3	1·97
Second feed heater: 0·0913 (381·4−46·4) −0·9034 (42·4−15·5)	6·3	1·21
	522·7	100·00

to the Second Law analysis are listed. The following points should be noted :—

(*a*) The pump work appears as a greater percentage of the whole in Table III than

Table I

Point	Condition		T_0=520 deg. Fah. abs.			
	Pressure, lb/sq in abs.	Temperature, deg. Fah.	H	s	T_0s	b
1	1400	790	1360·8	1·5104	785·4	575·4
2	1400	700	1293·2	1·4545	756·3	536·9
3	350	680	1354·5	1·6459	855·9	498·6
4	350	431·8	1205·4	1·4977	778·8	426·6
5	1400	587·1	598·7	0·7967	414·3	184·4
6	80	510	1285·6	1·7388	904·2	381·4
7	20	280	1182·2	1·7744	922·7	259·5
8	0·507, 80 deg. Fah., q=0·92		1012·4	1·8801	977·7	34·7
9	14·7	65	33·0	0·0651	33·9	−0·9
10	14·7	90	58·0	0·1115	58·0	0
11	110	200	168·3	0·2938	152·8	15·5
12	110	300	269·7	0·4371	227·3	42·4
13	1400	331	301·4	0·4783	248·7	52·7
14	1400	335	306·1	0·4783	248·7	57·4
15	80	311·9	282·1	0·4533	235·7	46·4
16	14·7	192	160·0	0·2817	146·5	13·5

Units of enthalpy and availability, B.Th.U./lb. Units of entropy, B.Th.U./lb, deg. Fah.

it does in Table II. In many cases the pump work is neglected, but on an availability basis this work should be considered.

(*b*) Analysis by means of the availability function enables the losses in the heat exchangers to be calculated and their relative importance gauged. Note the comparatively large loss in the two feed heaters due to the heating of low-temperature feed by high-temperature steam.

TABLE IV

Irreversibility	B.Th.U.
H.P. turbine : (99·6−79·3)	20·3
L.P. turbine :	
(i) (105·9−62·2)	43·7
(ii) (99·0−83·7)	15·3
(iii) (163·1−123·4)	39·7
Condenser*	25·8
Reheaters	7·6
Contact heater	3·4
Hot-well	1·7
Feed heaters	16·6
	174·1

* It is assumed that the heat in the condenser cooling water is dissipated and lost to the surroundings at 60 deg. Fah.

(*c*) The irreversibility for each unit is listed in Table IV and the values tabulated were obtained using equation (15). As a check on the calculations it will be found that the total gain in availability (522·7) less the irreversibility (174·1), or the amount of energy rendered unavailable, equals the energy delivered (348·6). This last figure is found by summing the work quantities in Table I.

Example 2.—The circuit diagram for an open-cycle gas turbine plant is shown in Fig. 6. The h.p. turbine drives the two-stage compressor, fitted with an intercooler, and the l.p. turbine provides the useful work. Provision is made for an exhaust heat exchanger and this, together with the heater and reheater, completes the unit. In order to reduce the calculative work involved the working substance is assumed to be air and the specific heat is taken as constant. Heaters and reheaters have been provided instead of combustion chambers in order to overcome certain difficulties associated with the chemical change in the composition of the gases passing through the unit.

The following information and Tables V, VI and VII refer to the plant :—

Atmospheric pressure, 15 lb/in² abs.

Pressure ratio in each compressor stage, 2·5.

Isentropic efficiency ratio of each compressor stage, 0·85.

Isentropic efficiency ratio of each turbine stage, 0·87.

Working substance, air ; $\gamma=1\cdot4$ and $R=53\cdot3$.

Certain pressure losses were assumed at the heat exchangers, but these may be found from Table V, which lists for the points numbered on the diagram, values of temperature, pressure, entropy, enthalpy and availability. The entropy at any point is given by $s=c_p\log_e T_r-R/J\,.\,\log_e p_r$ (B.Th.U. per pound degrees Fahrenheit), where $T_r=T/520$ and $p_r=p/15$. From the values of γ and R, $c_p=0\cdot24$ and $R/J=0\cdot0685$.

The availability function b and the irreversibility were calculated using equations (9) and (15) respectively. The total irreversibility may be found by deducting the work done (56·00) from the total gain in availability from the surroundings (122·41). Subtraction gives the figure of 65·41, which is the value found by summation in Table VII.

Examination of the above table shows that the greatest loss occurs in the heat exchanger. This is due to the transfer of heat from high-temperature gases to relatively low-temperature air. On an energy basis it will be found that the exchanger has an "efficiency" of 80 per cent. The efficiency is taken to be T_5-T_4/T_9-T_4 in this case. On an availability basis the ratio of the transference of available energy is $64\cdot02/97\cdot31=0\cdot658$, which figure shows the inherent inefficiency of the heat exchanger to better advantage.

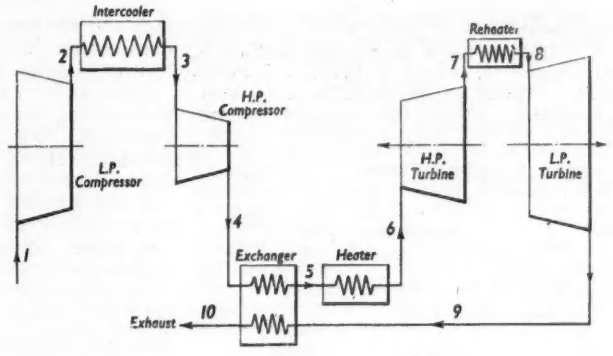


Fig. 6

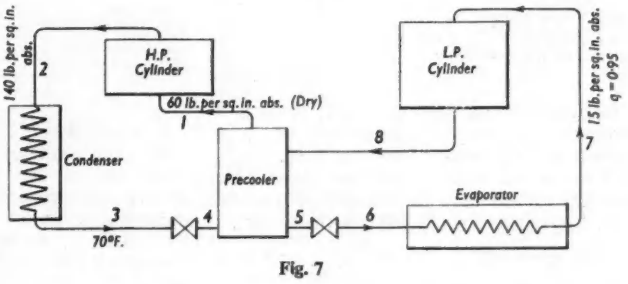


Fig. 7

Example 3.—The circuit diagram for a two-stage ammonia compression refrigerator is shown in Fig. 7.

TABLE VI—*Conventional Heat Account*

Energy input	B.Th.U./lb
Heater : 0·24×404	96·9
Reheater : 0·24×373	89·5
	186·4
Energy output	**B.Th.U./lb**
L.P. turbine : 0·24×233	56·0
Exhaust : 0·24 (901−520)	91·4
Intercooler : 0·24 (703·1−540)	39·0
	186·4

Thermal efficiency of plant : 56/186·4=0·3 or 30 per cent.

	B.Th.U./lb
L.P. compressor work	43·94
H.P. compressor work	45·62
H.P. turbine work	89·56
L.P. turbine work	56·00

In this example the following assumptions are made :—

(i) The ammonia vapour leaves the precooler and enters the h.p. cylinder dry saturated at 60 lb per square inch absolute pressure.

(ii) The dryness fraction of the vapour leaving the evaporator is taken as 0·95 and an isentropic compression efficiency ratio of 0·85 is taken for both cylinders.

(iii) In the condenser, where the fluid is undercooled to 70 deg. Fah., it is assumed that the heat given up by the ammonia is given to a large reservoir at a constant temperature of 70 deg. Fah.

(iv) It is assumed that the heat taken up by the ammonia in the evaporator is transferred from a large reservoir at the saturation temperature of the ammonia liquid.

(v) The temperature of the surroundings is taken to be 520 deg. Fah. absolute.

The properties of the fluid were taken from the *Refrigerating Data Book*[3] and it is found that for a flow of 1 lb of fluid through the evaporator there is a flow of 1·162 lb through the condenser. Table VIII shows the values of enthalpy, entropy and availability b at the points numbered on the diagram, Fig. 7.

TABLE V

Point	T deg. Fah. abs.	lb/sq in abs.	T_r	p_r	$c_p\log_e T_r$	$R/J\,.\,\log_e p_r$	s	$T_0 s$	H	b
1†	520·0	15·00	1·0000	1·0000	0	0	0	0	0	0
2	703·1	37·50	1·3521	2·5000	0·07240	0·06277	0·00963	5·00	43·94	38·94
3	540·0	36·50	1·0385	2·4333	0·00904	0·06091	−0·05187	−26·97	4·80	31·77
4	730·1	91·25	1·4040	6·0833	0·08142	0·12368	−0·04226	−21·98	50·42	72·40
5	1396·1	90·25	2·6848	6·0167	0·23703	0·12293	0·11410	59·33	210·26	150·93
6	1800·0	87·25	3·4615	5·8167	0·29801	0·12061	0·17740	92·25	307·20	214·95
7	1426·8	33·65	2·7438	2·2433	0·24224	0·05534	0·18690	97·19	217·63	120·44
8	1800·0	31·65	3·4615	2·1100	0·29801	0·05115	0·24686	128·37	307·20	178·83
9	1567·0	18·02	3·0135	1·2013	0·26474	0·01256	0·25218	131·13	251·28	120·15
10	901·0	15·00	1·7327	1·0000	0·13192	0	0·13192	68·60	91·44	22·84

The values in the above table are for 1 lb of air

TABLE VII

Availability gain	B.Th.U./lb
L.P. compressor	38·94
H.P. compressor	40·63
Exchanger	78·53
Heater	64·02
Reheater	58·39
	280·51
Availability loss	**B.Th.U./lb**
Intercooler	7·17
H.P. turbine	94·51
L.P. turbine	78·68
Exchanger	97·31
Exhaust	22·84
	280·51
Irreversibility	**B.Th.U./lb**
L.P. compressor	5·00
Intercooler	7·17
H.P. compressor	4·99
Exchanger	18·78
H.P. turbine	4·95
L.P. turbine	2·68
Exhaust	22·84
	65·41

TABLE VIII

Point	H B.Th.U/lb	s	$T_0 s$	$b=H-T_0 s$
1	620·5	1·2787	664·9	− 44·4
2	679·1	1·2932	672·5	6·6
3	120·5	0·2537	131·9	− 11·4
4	120·5	0·2579	134·1	− 13·6
5	75·9	0·1668	86·7	− 10·8
6	75·9	0·1762	91·6	− 15·7
7	573·0	1·3257	689·4	−116·4
8	657·1	1·3492	701·6	− 44·5

T_0=520 deg. Fah. abs.

TABLE IX.—*Conventional Heat Account Per Pound of Fluid Through Evaporator*

Energy input :	B.Th.U.
H.P. cylinder : 1·162×58·6	68·1
L.P. cylinder	84·1
Evaporator	497·1
	649·3
Energy output :	
Condenser : 1·162×558·6	649·1

Coefficient of performance=497·1/152·2=3·27.

The entries in Table X were obtained in the usual way. The details of the evaluation of the irreversibility in the condenser are as follows.

The decrease in the availability of the fluid as it passes through the condenser is given as 20·9 B.Th.U. This means that the maximum amount of work which could be delivered to the surroundings at 520 deg. Fah. absolute is 20·9 B.Th.U. and that (649·1−20·9), or 628·2 B.Th.U. of heat, would be rendered unavailable. In the case under consideration the heat is transferred

to a reservoir at 530 deg. Fah. absolute and the energy available at this temperature is $10/530 \times 649 \cdot 1$, or 12·2 B.Th.U., leaving (649·1−12·2), or 636·9 B.Th.U. of heat unavailable. Thus the increase in the

TABLE X

Availability gain	
H.P. cylinder : 1·162×51	59·3
L.P. cylinder	71·9
	131·2
Availability loss	
Condenser : 1·162×18	20·9
Throttling (3)–(4) : 1·162×2·2	2·6
Throttling (5)–(6)	4·9
Mixing in precooler: 1·162 (44·4−13·6)−(44·5 −10·8)	2·1
Evaporator : (116·4−15·7)	100·4
	130·9
Irreversibility	
H.P. cylinder : (68·1−59·3)	8·8
Condenser : (20·5−12·2)	8·3
Throttling (3)–(4)	2·6
Mixing in precooler	2·1
Throttling (5)–(6)	4·9
Evaporator	0
L.P. cylinder : (84·1−71·9)	12·2
	39·3

unavailable energy in the actual process is given by (636·9−628·2), or 8·7, which is the same as comparing 20·9 and 12·2.

The overall increase in the unavailable energy, or the total irreversibility, may be found by evaluating (T_0Q/T) for the system.

This gives $520\frac{649 \cdot 1}{530} - 520\frac{497 \cdot 1}{432 \cdot 4}$, or 636·9 −597·8=39·1, which value compares favourably with the value found by summing the losses in each part of the system. In the above expression the decrease in unavailable energy (597·8) at the evaporator is compared with the increase in unavailable energy (636·9) at the condenser, the difference or gain in unavailable energy (39·1) is the same as would be obtained by comparing the actual work (152·0) with the ideal minimum work (112·9).

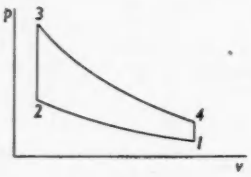


Fig. 8

It is seen from Table X that the largest losses occur in the cylinders and that the losses incurred elsewhere are small. The losses in the heat exchangers must be of a low order if the difference in temperature between the fluid and the surroundings is small.

Example 4.—A high-speed compression-ignition engine has a volume compression ratio of 20, and it is assumed that the cycle of operations follows the constant volume cycle (Fig. 8). To overcome certain complications in a problem of this kind some assumptions and simplifications have been made. Briefly, these are as follows :—

(i) Air alone fills the cylinder at the beginning of suction.

(ii) Exhaust takes place when the piston reaches the end of the working stroke.

(iii) The exhaust and suction strokes take

TABLE XI

Point	p lb/sq in abs.	v cu ft/lb*	T deg. Fah. abs.
1*a*	14·7	13·350	530
1	14·5	15·320	600
2	845·8	0·766	1750
3	1933·0	0·766	4000
4	43·49	15·320	1700
5	14·7	33·570	1281
5*a*	14·7	13·890	530

* Volumes per pound of air : state 1*a*, air at test house conditions ; state 5*a*, exhaust cooled to test house temperature.

place so that there is no mixing of the fresh charge with residual gases.

It is not unreasonable to make the above assumptions since the compression ratio is high and the loss due to the mixing of the fresh charge with the residual gases will be relatively small.

Allowing for a loss of heat to the cylinder walls during compression, combustion and expansion, Table XI gives the values of pressure, volume and temperature at the main points of the cycle.

If the fuel oil has the composition by weight : C, 0·85 ; H, 0·15, and 100 per cent excess air is supplied, the volumetric composition of the post-combustion mixture is as follows :—CO_2, 0·0662 ; H_2O, 0·0701 ; O_2, 0·1013 ; N_2, 0·7624.

TABLE XII—*Conventional Heat Account Per Pound of Air*

Heat supplied	651·9 B.Th.U.	100 per cent
Cycle work	260·8	40
Loss to jacket water	189·1	29
Heat in exhaust	202·0	31
	651·9	100

C.V.=19,400 B.Th.U. per pound at 70 deg. Fah. The heat flow to the cooling water is made up of the following items :—Loss during compression, 14·5 ; loss during combustion, 88·8 ; loss during expansion, 85·8 B.Th.U. per pound of air. This gives a total of 189·1 B.Th.U. lost to the jacket water.

In order to make an analysis on the basis of the Second Law it is necessary to relate the internal energies and entropies of the air and products so that the values have a common base. This may be done as follows :

Entropy.—Taking the composition of air by volume as 0·79 (N_2) and 0·21 (O_2) the entropy of 1 lb of air at 530 deg. Fah. absolute is 1·608 B.Th.U. per pound degree Fahrenheit, assuming that each gas fills its own partial volume at standard pressure (14·7 lb per square inch absolute). The entropy of the products at the same temperature and pressure, each gas filling its own partial volume at standard pressure, is 1·664 B.Th.U. per pound of air degree Fahrenheit. Since there are 1·0336 lb of products per pound of air, the energy and entropy quantities must be drawn up on the basis of 1 lb of air or of 1 lb of products. The writer has chosen 1 lb of air as the basis for his analysis. Thus the entropy of the products at any point must be reduced by 0·056 to relate the entropy values to those of air.

Energy.—The total internal energy of the air before combustion commences must include the energy of the fuel, although the fuel has not yet been injected into the cylinder. The energy of the fuel is assumed to be the heat which is liberated at 70 deg. Fah., in this case 651·9 B.Th.U. per pound of air. Hence the internal energy values of the air before combustion commences have to be increased by an amount equal to 651·9 B.Th.U. Unfortunately, the problem is not as easy as this. It will be found at any temperature that the internal energy of 1 lb of air is not equal to the internal energy of the corresponding amount of gaseous products. Thus there are, in effect, two problems to overcome in this connection and both can be overcome in the following way. Table XIII lists the internal energy, entropy and availability values for the points already chosen. The entropy values are for 1 lb of air and have been corrected as indicated above. The values of E listed for points (3), (4), (5) and (5*a*) are the values of the internal energy of the products of combustion associated with 1 lb of air. If there were no loss of heat during combustion the value of E at the point (2) would be the same as that at the point (3), i.e. E_2=912·9 ; but a loss of heat to the jacket cooling water, amounting to 88·8 B.Th.U. per pound of air, occurs during combustion. Hence, E_2=912·9+88·8 =1001·7 B.Th.U. per pound of air. The value of E_1 will be less than the value of E_2 by the amount of the difference between E_2 and E_1, which is 215·9, and similarly for the point (1*a*). In this way, the energy values are related. The availability is calculated

TABLE XIII

Point	s	E	$\frac{p_0v}{5 \cdot 404}$	T_0s	b	Availability gain+*ve* loss−*ve*
1*a*	1·608	773·7	36·3	852·2	− 42·2	—
1	1·639	785·8	41·7	868·7	− 41·2	+1
2	1·631	1001·7	2·1	864·4	−139·4	+180·6
3	1·850	912·9	2·1	980·5	69·7	−209·1
4	1·852	335·9	41·7	981·6	−604·0	−534·3
5	1·844	244·5	91·3	994·3	−658·5	− 54·5
5*a*	1·608	96·6	37·8	852·2	−717·8	− 59·3
						−675·6

Irreversibility

Suction	−1*
Compression (230·4−180·6)...	49·8
Combustion	209·1
Expansion (534·3−491·2)	43·1
Exhaust	54·5
Heat lost in exhaust	59·3
	414·8

The properties of the working fluid were taken from *Tables of Properties of Gases*,[9] prepared by Dr. E. W. Geyer and the writer.

* This figure corresponds to a decrease in the unavailable energy, but it must not be thought that suction in this engine has some property of high reversibility. If a detailed analysis of the suction and exhaust strokes were made a degree of irreversibility would appear.

using equation (5) and the irreversibility using equation (15). If it is assumed that the heat lost to the jacket cooling water is dissipated at the temperature of the surroundings (T_0=530 deg. Fah. absolute), then none of this heat is available and the first term in equation (15) is zero.

The analysis shows that there is a decrease in the available energy of 675·6 B.Th.U. as the fluid passes through the cycle. All this energy is not rendered unavailable as 260·8 B.Th.U. of work are delivered to the surroundings. Hence the irreversibility, or the increase in the unavailable energy amounts to (675·6−260·8)=414·8 B.Th.U., the value given in Table XIII. It is to be noted that the greatest irreversibility occurs during combustion, although there are other losses due to the transference of heat to the jacket water and to the dissipation of the heat in the exhaust.

The writer does not claim that the four examples considered here represent the performance of any working unit. When planning out examples to illustrate certain features it is often convenient to invent a system which bears a close resemblance to an actual unit in preference to using actual test figures. The writer trusts that the method of analysis illustrated here will prove attractive to engineers and it is hoped that greater use will be made of Second Law analysis in the future. The above work was carried out in the Department of Mechanical Engineering, University of Glasgow, with facilities provided by Professor James Small.

BIBLIOGRAPHY

[1] Goodenough, *Principles of Thermodynamics*, Henry Holt and Co., N.Y., 1929.

[2] Kiefer and Stuart, *Principles of Engineering Thermodynamics*, John Wiley and Sons, Inc., New York.

[3] Zemansky, *Heat and Thermodynamics*, McGraw-Hill Book Company, Ltd., New York and London.

[4] Keenan, *Thermodynamics*, John Wiley and Sons, Inc., New York.

[5] Keenan, *Mechanical Engineering*, Vol. 54 (1932), pages 195–204.

[6] Darrieus, *Engineering*, 1930, pages 283–285 (trans.).

[7] Lewis and Randall, *Thermodynamics*, McGraw-Hill Book Company, Inc., New York and London.

[8] *The Refrigerating Data Book*, American Society of Refrigerating Engineers—reprinted August, 1944.

[9] Geyer and Bruges, *Tables of Properties of Gases*, Longmans Green and Co., Ltd., London (1948).

P. and O. Liner "Arcadia"

No. III—(*Continued from page 323, February 26th*)

The liner "Arcadia" recently joined the fleet of the Peninsular and Oriental Steam Navigation Company and sailed on her maiden voyage in that company's service to Australia on February 22nd. A total of 679 first and 735 tourist-class passengers are carried and the ship, which has a length overall of 720ft and a gross tonnage of 29,734, is propelled at a service speed of 22·5 knots. Two sets of double reduction geared turbines develop a total propulsive power of 34,000 s.h.p. and take steam at 500 lb per square inch pressure and 800 deg. Fah.

Deck and Auxiliary Machinery

ACCESS to the general and insulated cargo spaces is by six hatches which are served by a total of sixteen 3-ton and two 10-ton derricks, mounted at the forward and main masts and on derrick posts and operated by eighteen electrical winches. These have a capacity of 3 tons at 100ft per minute, 1·5 tons at 200ft per minute, and a light hook speed of 450ft per minute, and are driven by 26 h.p. motors. Six of the winches, all of which have been supplied by Clarke Chapman and Co., Ltd., are self-contained and the remainder remote controlled. The same company manufactured the capstans and the windlass; the latter is suitable for handling 3⅛in diameter Tayco cable and is powered by two 112 h.p. motors fitted on the deck below. On one motor the windlass can exert a pull of 90 tons at 10·5ft per minute and the same amount at twice the speed on two motors. There are two capstans forward driven by layshafts from the windlass and each can pull 19·5 tons at 45ft per minute or 7·5 tons at 120ft per minute. Two other capstans are mounted aft on "C" deck; they are self-contained units each driven by a 64 h.p. motor and able to exert a pull of 18 tons at 35ft per minute.

Steering of the ship is effected by Brown Brothers' electric-hydraulic gear, which has four rams of 13in diameter at 33in normal radius and a working stroke of approximately 46½in. There are two 70 b.h.p. electrical motors, each driving a variable-speed gear pump and working pressure in the system is 1320 lb per square inch. The streamlined semi-balanced rudder, which is supported on a pedestal bearing at the steering gear flat, has an area of about 283 square feet, a working angle of 35 deg., and is designed for a speed of 22½ knots ahead and 15 knots astern, and can be moved from hard over to hard over in thirty seconds, the effective torque at 35 deg. being about 500ft-tons.

Brown Brothers and Co., Ltd. has also fitted its Denny-Brown stabilisers, similar to those fitted in "Chusan" and described in THE ENGINEER of June 30, 1950, designed to reduce the rolling motion of the ship, due regard being paid to the displacement of the ship on departure and arrival and the corresponding metacentric heights, the service speed and the average rolling period. The fins, of fabricated construction, have an outreach from the hull of 14ft and a fore and aft width of 7ft, representing an area of 98 square feet. At 20 deg. angle of tilt and 22·5 knots the normal load on each fin is over 90 tons and the equivalent maximum righting moment is about 9400 tons-feet. There are two tilting pumps driven by 80 h.p. motors, one servo pump driven by a 15 h.p. motor, and an auxiliary pump, and the fins, which project from the hull at the turn of the bilge and lie in the normal streamline flow, can be extended in about four minutes and housed in approximately three minutes. A rapid reversal of the angle of the fin, at the commencement of each roll of the ship, is essential in order to ensure maximum damping effect and the tilting motors can move the fins from hard over to hard over—that is, through 40 deg.—in about one and a half seconds. This time can be compared with the thirty seconds required to move the rudder through 70 deg. Our illustration of the starboard fin shows that the tilting gear consists of a four-ram arrangement instead of the earlier two-ram system. The maximum torque of the tilting cylinders at 20 deg. is 115 tons-feet and the hydraulic pressure 1200 lb per square inch. The stabilising equipment is housed in a compartment just forward of the boiler-room, access to this space being through a watertight door to port in the boiler-room forward bulkhead. The total weight of the gear, including an allowance for the lost buoyancy, due to the fin boxes, is approximately 190 tons.

Drysdale and Co., Ltd., has supplied the sewage plant for the ship and it consists of three twin sets of "Centra-Syphon" expulsion equipment. Each set has a tank and two 4in/4in centrifugal pumps, one of which acts as a standby. Each pump has a capacity of 320 gallons per minute against a head of 40ft, and is driven by an electric motor of 8½ h.p.

Navigation and Safety Equipment

All the modern instruments and aids essential for the safe navigation of the ship are fitted in the wheelhouse and chart room, including Kelvin and Hughes compasses, Sperry gyro compass and repeaters, Kent clear-view screens, and Marconi radar equipment.

As a safeguard against the outbreak of fire an automatic sprinkler and alarm system manufactured by Mather and Platt, Ltd., is installed, and the ship is zoned by the provision of fire-resisting bulkheads, "Dreadnought" fire-resisting doors and fireproof doors at the lift entrances. Extensive thermal insulation is installed to prevent heat from the machinery spaces and galleys affecting the adjacent accommodation. There is also a Pyrene smoke-detecting installation. A total of fifteen watertight doors have been supplied by Mechans, Ltd.; four are power operated under Stone's electric control system, and can be controlled from the bridge, locally from either side of the bulkhead and also from a point above the bulkhead deck. The eleven hand-operated doors are also controlled locally or from above the bulkhead deck. Mechans, Ltd., has also built the complement of lifeboats consisting of ten boats to carry 145 persons, four boats of ninety-nine persons capacity, two to carry forty-eight persons, and two motor lifeboats to carry 136 persons, carried under gravity davits manufactured by Welin MacLachlan Davits, Ltd.

Propelling Machinery

Our accompanying line drawing shows the general arrangement of the engine-room which houses the main propelling machinery, constructed by the shipbuilders, and associated auxiliaries. The ship is propelled by two sets of impulse reaction geared turbines taking steam at 500 lb per square inch gauge and 800 deg. Fah., and developing a total normal ahead power of 34,000 s.h.p. at 130 r.p.m. of the propeller and a maximum of 42,500 s.h.p. at propeller revolutions of 140 r.p.m. The astern turbines develop up to 65 per cent of the normal ahead power.

Each propeller is driven by a set of turbines consisting of h.p., i.p. and l.p. turbines working in series, the h.p. turbine being of impulse reaction design and having a two-row impulse wheel, forged solid with the rotor, followed by five reaction stages totalling twenty-nine rows of segmentally fitted, end-tightened reaction blading. Mild steel packing is used and side locking strips of Lowmoor iron, and the turbine casing is of molybdenum alloy cast steel. There are seven expansions consisting of thirty-five rows of end-tightened reaction blading in the i.p. turbine, segmentally fitted to a hollow forged drum rotor. The casing is of cast steel. Thrust dummies are fitted to both h.p. and i.p. turbines and Michell thrust bearings take up the unbalanced axial thrust, while pulling-up gear, which can adjust the end-tightened clearance when running, is also fitted. The l.p. turbine, of double-flow design, has eleven single-row stages of segmentally fitted reaction blading in each half and a hollow forged drum rotor. The ahead part of the casing is of cast iron and the astern portion of cast steel. A three-row impulse wheel shrunk on to the forward end of the i.p. rotor and incorporated in the i.p. casing forms the h.p. stage of the astern turbine, and the l.p. stage consists of a three-row impulse wheel attached to the forward end of the l.p. rotor. Hecla A.T.V. steel has been used for all nozzle vanes and all impulse blades, which are fitted individually into the rotor and cylinder grooves. Reaction blades, which are assembled in sectors held at the roots by brazing and secured by serrated side locking strips, are of Monel metal and stainless iron. The h.p. ahead nozzle plates are fabricated while the h.p. and i.p. astern nozzle plates are of cast steel. Each turbine casing has double pocket steam glands at each end, the inner pockets being connected to

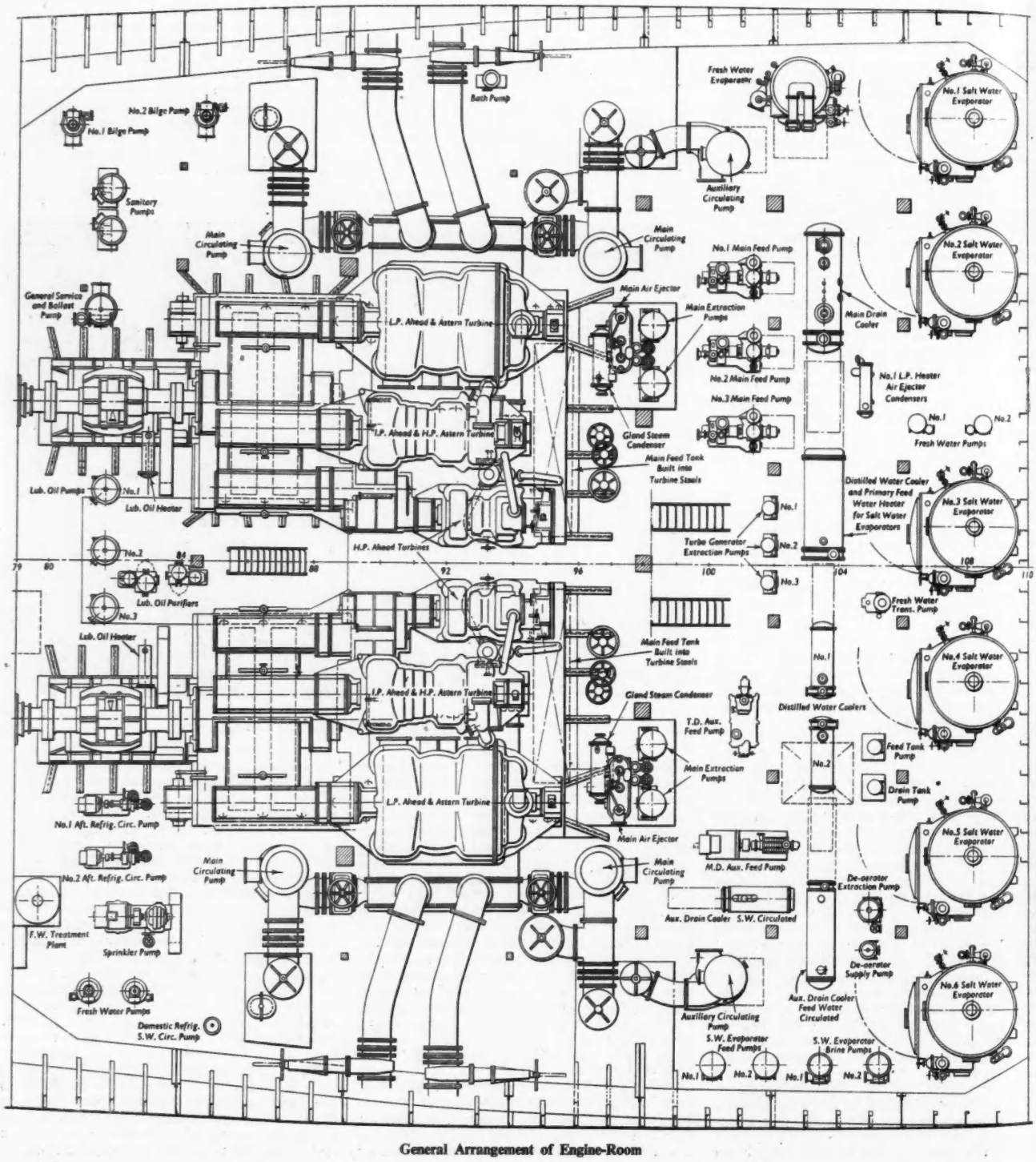
Operating Gear of Starboard Stabilising Fin

receivers and the outer pockets to the gland condenser. Aspinall cut-out governors shut off the steam to all turbines should the lubricating oil pressure drop below a given amount or if the revolutions exceed a predetermined figure. All turbine rotors are dynamically balanced and the turbines themselves are lagged with "Newtempheit" and magnesia blocks supplied by Newalls Insulation Company, Ltd.

Gearing

A flexible claw coupling connects each turbine to the double helical gearing, which is double reduction to the h.p. turbine and single reduction to the i.p. and l.p. turbines. A fabricated gear case houses the h.p. primary gears, which consist of nickel steel primary pinions and have 7/12in pitch all-addendum teeth, a pitch circle diameter of 13·71in, a face width of 31in, and a 3in gap. The forged steel primary wheels have a 34·49in pitch circle diameter. All the secondary pinions have central bearings, the h.p. pinions having a pitch circle diameter of 17·03in, while the corresponding diameter for the i.p. and l.p. pinions is 12·62in. The main wheels have a pitch circle diameter of 174·09in with a 49in face width, and have cast iron centres with shrunk-on forged rims. All the pinions are dynamically balanced and the main wheel statically balanced and the gear cases are fabricated. The gear ratios reduce the speed of the h.p. turbines running at 3600 r.p.m. and the i.p. and l.p. running at 1931 r.p.m. to a propeller shaft speed of 140 r.p.m. Electrically operated turning gear, fitted on the l.p. pinions, can turn the main shafting one revolution in ten minutes. Three "Vertoil" electrically driven oil pumps, each of 25,000 gallons per hour capacity against a head of 55 lb per square inch, draw lubricating oil through three magnetic filters and deliver it through five Autoklean "Flush Flo" strainers and three Serck coolers to gravity tanks which are of sufficient capacity to ensure a five minutes' supply of oil to turbines and gearing, in the event of pump failure. There are also two Titan lubricating oil purifiers, each of 350 gallons per hour capacity, associated with heaters capable of raising the temperature of 300 gallons of oil per hour from 70 deg. to 160 deg. Fah. Michell self-lubricating pivoted bearings carry the solid forged steel shafting, which has diameters of 21⅞in and 23⅝in for the intermediate shafting and the propeller shaft respectively, while the propeller thrust is taken by Michell single-collar thrust blocks. Siemens-Ford electrical torsion meters are fitted to each shaft to measure the power. Bulls Metal and Marine, Ltd., supplied the four-bladed, solid-manganese bronze propellers, which have a diameter of 19ft by 19ft 6in mean pitch and weigh about 24 tons.

(To be continued)



General Arrangement of Engine-Room

Electric Rolling Stock for Toronto Subway

The Toronto Subway runs under or alongside Yonge Street from Eglinton in the north to Union Station in the centre of the city, a distance of 4½ route-miles, with ten intermediate stations. This double-track line is designed for a maximum capacity of 40,000 passengers per hour to replace the 14,000 passenger-per-hour capacity of the surface tramcar system, leaving Yonge Street free for motor traffic. The multiple-unit electric rolling stock for the new subway is described here.

TO relieve street traffic congestion along Yonge Street, the main thoroughfare in Toronto, the city's Transit Commission decided more than four years ago to build a subway, closely following the route of the street from Eglinton on the northern outskirts to Union Station in the heart of the city. The line was designed to have a maximum capacity of 40,000 passengers per hour, exceeding by 26,000 that provided by the street tramcar system, which could therefore be abandoned, giving motor traffic unimpeded use of Yonge Street. Work on the scheme was begun four years ago and the cost was estimated at about 83,000,000 dollars.

Between Eglinton and Union Station there are ten intermediate stations—Davisville, St. Clair, Summerhill, Crescent, Bloor, Wellesley, College, Dundas, Queen and King. From Eglinton the line runs roughly parallel and to the west of Yonge Street, running underground at first and then coming to the surface until a point beyond Davisville, where the line crosses under Yonge Street to St. Clair on the east side of the street. From St. Clair to Summerhill the line is mainly surface and there is another surface section on both sides of Crescent Station, between Summerhill and Bloor. The remainder of the route is underground.

Approximately 2·7 miles of the route are in tunnel and the remainder in the open. It was decided to construct the subway portion of the project by the "cut-and-cover" method, as opposed to tunnelling. To minimise the extra traffic congestion caused by the civil engineering works it was necessary to restrict occupation to one "block" of Yonge Street at a time. In the densely built-up southern area, one block at a time was excavated to a depth of approximately 18ft; public utilities—gas, electricity, water, sewers, telephones, drains, &c.—were resited, and adjacent buildings underpinned. A temporary deck was placed over the excavation to allow resumption of normal street traffic, including tramcars. Further excavation, followed by laying of the railway tracks, then proceeded underneath the decking. In the less densely built-up areas both "cut-and-cover" and "open-cut" construction were employed; any houses directly in the way were demolished and adjacent buildings underpinned. Reinforced concrete bridges were provided for cross surface traffic. Tunnelling was employed only where the track passes under the Canadian Pacific Railway south of Summerville, and where it passes north-westerly from St. Clair under Yonge Street.

The twelve stations are all situated at intersections of the main cross streets, and are designed for quick and convenient passenger flow, with easy transfer from adjacent tram, bus, train, and trolleybus stations. All platforms are 500ft long and are outside the tracks, with the exception of those at the termini, where they are of the island form. The platform floors have non-slip surfaces and are level with the floors of the loaded subway cars. The walls are faced with coloured glass—each station having its own particular colour scheme—and the stations are illuminated by continuous lighting, the fittings being let into the ceilings. Escalators are provided at "deep" subway stations.

To enable the existing tramcars to run over the railway tracks, if required, the unusual track gauge of 4ft 10⅞in was chosen. An unusual method of track construction, dispensing with sleepers, is used, to minimise vibration and noise in the underground sections. The track bed is concrete, and rectangular steel support plates, set on heavy rubber pads and spaced at 2ft intervals, are secured to the track bed by grouted-in bolts. Flat-bottom rail of 100 lb per yard is laid on resiliently mounted plates and secured to them by a pair of countersunk bolts, each holding a spring steel rail clip. Running rails are Thermit welded together, thus obviating rail bonds, which would otherwise have been necessary, as these rails are used for the earth return circuit. Track in the open sections is of the conventional design, using creosoted wooden sleepers and crushed stone ballast. The live rail is laid outside the running rails and is supported on insulators at 8ft pitch. Accidental contact with the live rail is prevented by a covering of inverted L-shaped wooden boards.

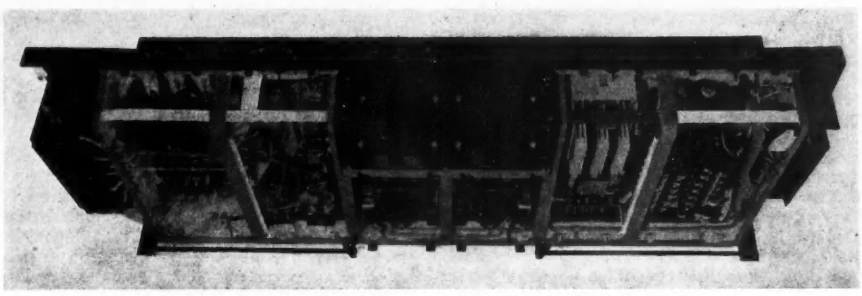


Fig. 2—Traction Control Equipment Frame with Covers Removed

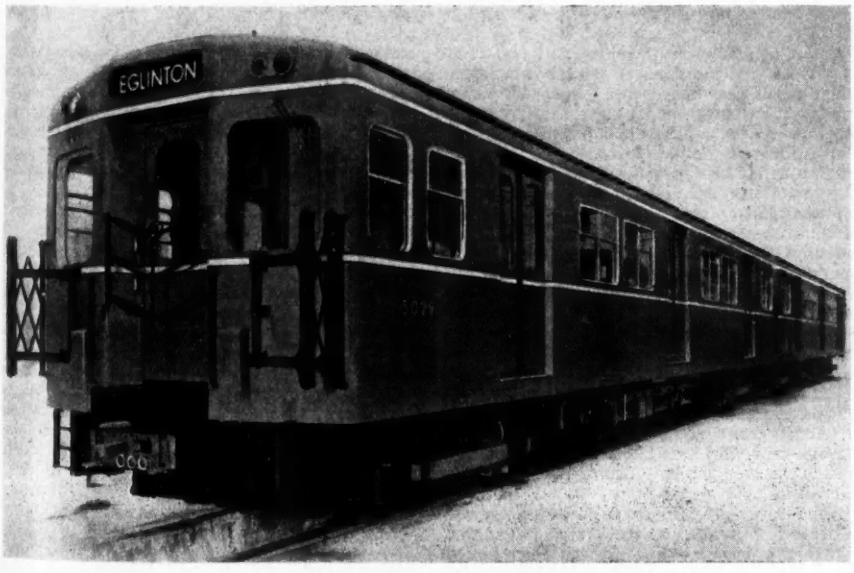


Fig. 1—Motor Coach for Toronto Subway

Electric Rolling Stock

An order for 104 complete cars was placed with the Gloucester Railway Carriage and Wagon Company, Ltd., who ordered from the British Thomson-Houston Company, Ltd., electric traction and auxiliary control equipment, together with all the control and auxiliary coach wiring. The subway cars are each 57ft long and 10ft 4in wide and will accommodate 230 passengers, with seats for sixty-two persons. Both accelerating and braking rates are high, the high rate of acceleration being achieved by motoring all axles.

The multiple-unit train sets are made up of one, two, three or four two-car units, according to traffic requirements. Each car of a unit (Fig. 1) has a driving cab at the outer end, which may be used either by the driver or the guard; it is small and occupies only a third of the car width. One car of each two-car unit carries the air compressor, the other carries the auxiliary motor generator set. The superstructure, comprising the car underframe and body, is of all-steel integral design. Precautions have been taken against fire risk, and the body panels are specially insulated against both noise and vibration. The car interior is lined with formica plastic sheeting. There are three electro-pneumatically controlled double-leaf doors each side of a car, and in case of emergency a pair of doors can be operated from either inside or outside the car.

Four of the cars are of aluminium alloy construction, and, to allow comparative current consumption to be assessed, these cars and four steel cars are each fitted with a kilowatt-hour consumption meter.

Traction Control

The B.T.H. control scheme provides for series-parallel control of the four traction motors, which are arranged in pairs permanently connected in series. The trains are under multiple unit control from one driving position.

All the main items of traction control equipment, including two line circuit-breakers, camshaft accelerating unit, reverser, series-parallel transfer switch, field shunting contactors, accelerating, volt-ampere and overload relays, &c., are mounted in an aluminium alloy framework (Fig. 2) carried on the underframe. Easily removable dustproof covers are fitted. The two line breakers are fitted with extension arc chutes, which project out of the framework. All power

cables are fitted with "quick-release" connectors, thus enabling the complete unit to be removed quickly from the underframe.

The control equipment comprises a number of electro-pneumatic units, including a cam-operated contactor group, which controls the acceleration. Each contactor in closing cuts out a section of starting resistance, the order of closing being determined by the camshaft. A pinion on the camshaft engages with a rack mounted between two pistons in a cylinder; one piston operates under air pressure and the other under oil pressure. The camshaft notches up under oil pressure in nine steps to the full series position. Point-to-point movement is controlled by a current relay which arrests the camshaft movement by means of an electro-magnetically operated pawl engaging a star wheel on the camshaft. When the full series position has been reached a series-parallel transfer switch operates to connect the two pairs of motors in parallel, each with its own section of resistance reinserted. Pressure on the oil is then released and transferred to the air cylinder, which rotates the camshaft in the opposite direction, still under control of the current relay. This reverse movement again cuts out the starting resistance sections step by step until the camshaft returns to its initial position, at which stage the two pairs of motors are connected in full parallel. Two steps of field weakening, under current control, are provided. The use of a large number of accelerating points provides rapid and smooth acceleration.

The two line breakers, the reverser, and the series-parallel switch are all electro-pneumatically operated. The line breakers open the circuit under normal switching and protect the equipment by opening when the overload relay operates.

The traction control units on any or all the cars of a train may be tested for correct operation (without applying power to the motors) by depressing the control test pushbutton and operating the master controller handle. Correct operation is proved by the illumination of an indicator lamp in the cab. A test socket is provided in each cab which facilitates quick location of a faulty equipment.

The lightweight starting resistors comprise ten "RP" units (Fig. 3), manufactured from edge-

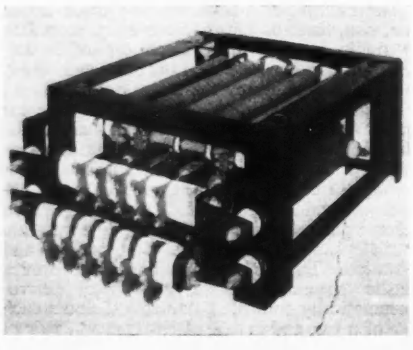


Fig. 3—Starting Resistors of Aluminium-Chromium Alloy Steel

wise-wound aluminium-chromium alloy steel strip of high specific resistance and low temperature coefficient. These resistors are mounted in an angle iron framework under the car and tertiary insulation is provided.

The main traction circuit is protected by a ribbon fuse, mounted on the underframe next to the main auxiliary and heater fuses, which are all "HRC" cartridge fuses.

The auxiliary contactors, 600V and 50V, are mounted in line in a sheet steel box carried below the solebar. The box has easily removable dust-tight covers and the contactors are readily accessible for maintenance purposes. Each 600V contactor is provided with two breaks in series, each with its own blow-out coil. On every car there is a double-pole, double-throw test switch, which is used in the depot in conjunction with a 600V plug and trailing cable. When the switch is in the "test" position the traction and heater

Fig. 4—Driver in Control Cab

circuits are isolated, but a 600V supply is available for the motor generator, compressor and lights.

Driver's Cab Equipment

Because of the confined space in the driver's cab most of the auxiliary electrical equipment is flush mounted. The partition behind the driver accommodates control and auxiliary cut-out switches, fuses, door control switch, traction control equipment cut-out switch, ammeter and test sockets, and cab heaters with their switches.

The master controller, of the shallow desk form, is cam operated and has only three operating positions. In the "shunt" position all four motors are connected in series with the starting resistance. In the "series" position the resistance is all cut out and the motors are in series across the supply. In the "parallel" position the motors are connected in series-parallel across the supply. The field shunting steps are taken automatically under current control in the "parallel" position. By means of an accelerating rate switch the driver can select any one of three accelerating rates; this enables the acceleration to be maintained under varying load and rail adhesion conditions.

To ensure that a train is operated from one position only, the driver is provided with a removable key which operates a driver's control switch and is trapped in the "on" position. This key also operates the traction control equipment cut-out switch.

The master controller is mounted for left-hand operation (Fig. 4), and to the right of it is the electro-pneumatic brake controller. The two mercury retarder switches, which control the rate of braking, are mounted above the cab door. In the corner of the cab there are six push-buttons for door control and inter-car signalling. Flush mounted in the left-hand corner pillar are two brake pressure gauges, a battery voltmeter and a bank of six coloured miniature indicator lamps. Two green lamps indicate doors shut, two orange lamps prove electro-pneumatic brake and retarder supplies, a red lamp shows only when a motor generator is not operating, and a blue lamp lights when all traction control units on the train have operated to the final parallel position.

On the right-hand corner pillar there are eight pushbuttons; they are the motor generator "start" and "stop," "signal bell," "couple" and "uncoupled," "overload set" and "overload trip and test," and "driver's switch shunt." The last-mentioned button provides an alternative feed to the motor generator start and stop buttons when the driver's switch is not closed, to enable unskilled maintenance staff to switch on the motor generator set, if required for car heating.

There are a number of provisions on the electrical equipment of the cars which are not normal British practice, and they may be summarised as follows:—

(1) The master controller is operated by the driver's left hand and is fed from a traction control relay, the operating coil of which is energised through the door interlocks, of which there are ninety-six in series on an eight-car train. A combined door cut-out and interlock shorting switch is provided for each door. In addition, a sealed master switch in the driving cab can be used in an emergency to cut out the traction control relay.

(2) The starting signal is visual and not audible.

(3) The door circuits are designed to cater for a maximum of four operational guards on one eight-car train. The zoning device operates automatically and divides the train into the same number of zones as there are guards.

(4) Both forward and rearward door "open" and "close" control pushbuttons are provided.

(5) Guards can signal to each other and to the driver by buzzer, but the driver can only signal to the guard by bell.

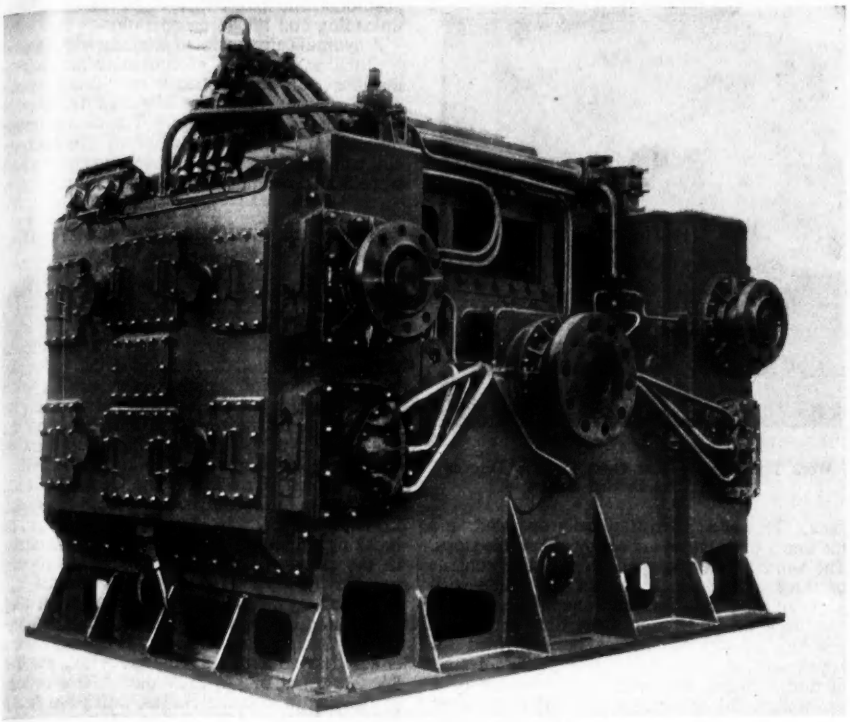
(6) Thermostatic heating control is provided.

Four-Engine Reverse-Reduction Gear

A NUMBER of factors in recent years have influenced the choice of the prime mover for ships of all sizes and engaged in a wide variety of trades and, apart from the change over from coal to oil as a fuel, there has been a rapid expansion of the employment of the diesel engine as a main propulsion unit. This swing has been largely caused by the economics involved in a particular service, but following the general establishment of the oil engine for the powering of ships there has been the development of the engine itself. There has been a steady increase in the power range by means of supercharging and other means, but in the lower power groups the tendency has been to increase the revolutions to obtain a smaller and lighter engine. However, to take full advantage of these higher rotational speeds and to maintain the propeller at its efficient speed the incorporation of a reduction gear is necessary and the adoption of a reverse-reduction gear effects further economies in the main engine by reducing the demand for starting air.

One such gear is the S.L.M. oil-operated marine transmission system which is manufactured by Modern Wheel Drive, Ltd., Slough, in a range of sizes suitable for installation in tugs, trawlers, ferries, coasters and deep sea cargo ships. The gear is of robust design and the transmission is simple, consisting as it does of few working parts so that manœuvring is smooth. In all the gears the wheels are in constant mesh and both the ahead and astern wheels incorporate an oil-operated coupling which consists of two inner and two outer members. The latter are carried by and are free to rotate on the sleeve or hub of the inner members which are carried on longitudinal splines on the secondary shaft. Since, as previously noted, the gearing is in constant mesh, the primary shaft causes the outer member to rotate about the sleeve of the inner member, but no transmission of motion can occur until the inner member is brought into contact with the inner face of the corresponding outer member. This contact is achieved by the admission of oil under pressure into the space between the inner members which are then forced to slide axially along the splines until working contact between inner and outer members occurs. Contact is maintained until the oil pressure is released and then oil pressure on the opposite face forces the inner members back to their idling position.

A pump supplies the oil under pressure and the system consists of a by-pass valve, a control cock and ducts for leading the oil at correct



Four-Engine Reverse Reduction Gear

volume and pressure to operate and lubricate the couplings. A simple lever on the control cock when moved to one of three positions, marked "ahead," "stop" and "astern," causes the coupling to engage or disengage and the control is positive and instantaneous. Full ahead to full astern takes only a matter of about two seconds and there is no possibility of more than one coupling being engaged simultaneously.

The present-day trend towards multi-engined ships has called for the transmission of power from two or more high-speed engines to a single propeller shaft and the company has built a number of twin-engine reverse-reduction gears. Last week we were able to pay a visit to the works of Modern Wheel Drive, Ltd., to inspect the first large four-engine reverse-reduction gear.

This unit, which can be seen in the photograph reproduced herewith, is a Mark 4.M.W.R., size 6 gear and is designed to transmit a total of 8000 h.p. from four uni-directional diesel engines to a single propeller shaft and to effect a speed reduction in the ratio of $4\frac{1}{2}$: 1. The casing is fabricated from mild steel plate and suitably stiffened to carry the loads at the bearings, which are of gun-metal, white-metal lined while the design ensures that all bearings are easily accessible so that the removal of shaft assemblies is simplified. In addition provision has been made for inspection covers of ample size over the gear trains. Each of the four engines drives through an oil-operated clutch, gear cut on the outside diameter, which meshes with a second clutch and each clutch drives a pinion which meshes with the final wheel to drive it in either the ahead or astern direction. A master cock controls the flow of oil to the selected clutch to give the required rotation, and small levers on the master control cock enable each engine to be isolated from the gearbox if and when required. The control is finger-light and each section of the master cock is connected to a solenoid switch which causes the fuel valve of an engine to close, so that in the event of an engine being disengaged the reduction in oil pressure causes the fuel supply to be shut off from that particular engine so that it cannot race.

Incorporated with the gearbox is a hand-operated turning gear which drives on to the final wheel and is positively located in both engaged and disengaged positions. To prevent any engine driving into the gear while the turning gear is engaged there is an interlocking arrangement with the control cock so that the oil supply is cut off from the cock to make it impossible to engage any engine. Likewise a piston loaded from the gearbox oil system prevents the accidental engagement of the turning gear while the main gear is transmitting power. Oil for the system is supplied by an independent electrically-driven gear pump which draws oil from the gearbox sump and discharges through filters and a cooler to the main supply and thence to the control cock and bearings. Lubrication of the final drive is by sprays supplied through a pressure reducing valve from the main supply.

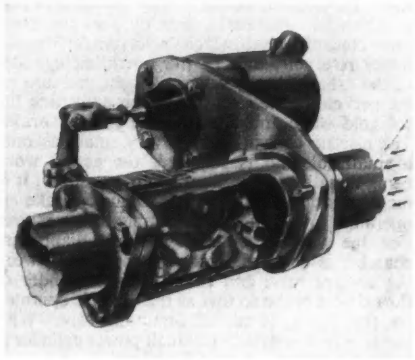
While on this visit to see the new four-engine reverse-reduction gearbox opportunity was taken to make a brief tour of the works to see some of the many gearboxes at present under construction, and it was of interest to note that the company has an epicyclic reverse-reduction marine gear undergoing tests. The gear at present on the test bed is a small unit which incorporates oil-operated clutches and is rated to transmit 700 b.h.p. at 2000 r.p.m. with a reduction ratio of 40 : 1. A short visit was paid also to the new gear-cutting shop, which is equipped with hobbing and generating machines and in which the temperature is controlled to plus or minus 1 deg. to increase the accuracy of the gear cutting. The equipment installed in the shop includes machines supplied by W. E. Sykes, Ltd., an Orcutt gear grinder and the latest Gould and Eberhardt hobbing machine which weighs about 50 tons and is mounted on a raft of concrete some 14ft thick. This machine is capable of gear-cutting wheels up to 8ft in diameter with a face width of 36in to a very high degree of accuracy.

Exhaust Braking System

An improved version of the "Oetiker" exhaust brake valve, based on the original design, is now being produced by Parkwood (Brakes), Ltd., Windmill Road, Sunbury-on-Thames. It is illustrated herewith and incorporates operating equipment by Clayton Dewandre Company, Ltd. Although exhaust braking has only recently been considered in this country, the original "Oetiker" unit was first produced in Switzerland over twenty-five years ago, and is now very widely used on the Continent.

The exhaust valve itself, which embodies a butterfly throttle, is fitted between the exhaust manifold and the silencer. In operation the engine becomes a single-stage, low-pressure compressor, operating at between 35 lb and 45 lb per square inch. Although the pressure is relatively small the amount of braking power transmitted to the driven wheels is nearly equivalent to the engine output. The external operating lever of the valve is connected to a shaft carrying a relay lever, which is coupled by a link to the low-pressure side of the butterfly. The arrangement requires no shaft seals, which have to be replaced and the danger of seizure is eliminated. Periodic cleaning of the valve is not necessary.

The reduction in vehicle running costs is claimed to be considerable, as with correct use brake lining wear can be reduced by 25 to 50 per cent, less frequent brake adjustment is



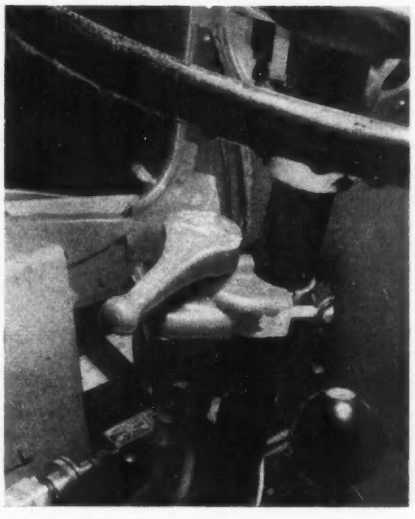
Exhaust Brake Valve with Air Pressure Operating Cylinder

necessary, brake drums have less arduous wear, and tyres have an added life due to the smooth application of braking, since it is impossible to lock the wheels under the varying conditions. The fitting of the exhaust valve is a simple operation, which calls for the cutting out of a section of the exhaust pipe to accommodate the valve unit. Flanges supplied with the valve are welded on to the open ends of the pipe and the unit is bolted into position, asbestos packings being used at the joints.

On Continental vehicles the usual method of operation is by a hand lever coupled to the exhaust brake valve by means of rods and linkage. In the modern underfloor engine vehicle with the driver at the front and the exhaust valve well to the rear, such a system is impracticable.

Other systems use an electrical solenoid mounted on the actual valve, but this has the disadvantage of being an additional load on the battery system, especially since the generator charge is small when the exhaust brake is applied.

The method of operation developed by Clayton Dewandre Company, Ltd., makes use of the



The Air Pressure Hand Control Mounted on the Steering Column

power available on most commercial vehicles in the vacuum or air pressure brake system. The various methods of operation can be controlled independently by a hand valve on the steering column, or automatically by the brake or the accelerator pedal.

The vacuum hand control system, as illustrated, consists of a hand-operated valve, which is mounted on the steering column. Vacuum from the reservoir is connected to the valve and the outlet from the valve is piped direct to the operating cylinder of the exhaust brake valve.

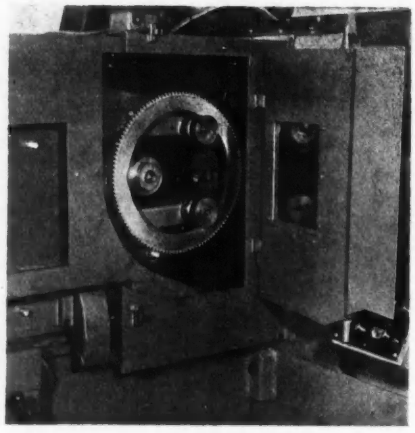
In the system using air pressure the position of the operating cylinder is changed over, since the air pressure system has a push stroke.

Brake pedal control for both vacuum and air pressure systems employs a "Micro" switch operated by a special pad mounted over the existing pedal. The switch controls a solenoid operated vacuum or air pressure control valve, which is connected to the brake reservoir, and to the operating cylinder of the exhaust brake valve. A light pressure on the pad closes the electrical circuit activating the solenoid valve and applying the exhaust brake. The electric consumption is very small, as only a small solenoid is required, the actual work being done by the vacuum or air pressure. It is most desirable, when the exhaust brake is operated, to cut off the fuel supply to the engine. For the vacuum systems a small diaphragm chamber is connected into the pipeline between the control valve and the operating cylinder of the exhaust brake so that as the brake is operated the fuel supply is cut off simultaneously. With the air pressure systems a small power cylinder is utilised in exactly the same way.

Duplex Grinding Machine

PARTICULARS have been received of a special duplex surface grinding machine recently built by F. E. Rowland and Co., Ltd., of Reddish, near Stockport, for the Morgan Crucible Company, Ltd. This machine is designed for grinding on an automatic cycle the faces of sintered bronze clutch discs up to 18in diameter. These discs consist of a sintered bronze ring on each side of a central toothed steel plate and they have to be ground uniform and parallel to within 0·001in to 0·002in. The discs are not particularly rigid and as sintered bronze is removed easily both the machine and work holding fixture had to be of rigid and accurate construction to maintain consistently the tolerances permitted.

The general arrangement of the duplex grinder can be seen in one of the illustrations on this page. It has a fabricated steel plate bed with large section cast iron slideways carrying the grinding wheelheads. These wheelheads are driven by individual 25 h.p. motors through vee-belts and they are equipped with inserted nut abrasive disc grinding wheels mounted on a heavy steel backplate. Fitted at right angles to the front of the main bed is a fabricated steel extension on which is mounted the work fixture



Work Fixture with Door Open to Show Disc on Support and Driving Rollers

slide. This slide is hydraulically operated, and the limits of its travel are set by adjustable stops. The work fixture mounted on the slide consists of three rollers which contact the inside periphery of the clutch disc, and one of these rollers acts as a driver to rotate the disc during the grinding operation. Means are provided for adjustment of the rollers to suit different sizes of discs. Work is clamped in the fixture by a hydraulic cylinder which moves the lower front roller to be seen in our second illustration.

The machine is hydraulically operated throughout, the power being provided by a motor-driven pump. The hydraulic valve control gear and push-button control station are conveniently arranged for operation at the work loading side of the machine. Work is rotated during the grinding operation by a hydraulic variable speed unit through a worm reduction gear, and the speed of rotation can be adjusted to suit the diameter of the workpieces being ground. As can be seen the work fixture is totally enclosed by a sheet metal guard in which a door is provided for the loading and unloading of discs. This door is interlocked so that the automatic cycle of the machine cannot be started until the door is closed.

In the operating cycle once a disc has been loaded and the door closed a push-button is depressed. The work carriage then moves forward into the grinding position and at the same time rotation of the work piece begins. At the limit of the work carriage in-feed the two wheelheads move inwards to grind the disc at a controlled feed rate until they meet stops. At this stage the wheels dwell for a predetermined period which can be set from 5 to 30 seconds as required. At the end of the dwell period the wheelheads reverse and stop at the open position whilst the work carriage moves outwards to the loading position. The fixture then stops rotating for the unloading and reloading operation.

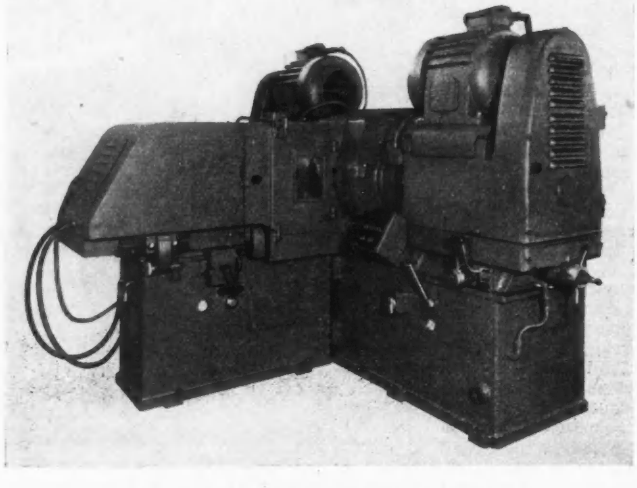
A hydraulically-operated grinding wheel dresser is fitted at the rear of the machine and the machines can be supplied with hydraulic wheel compensation equipment operated from push-buttons at the control station. This compensation mechanism operates a valve in the hydraulic circuit which applies the feed independently to each wheelhead to compensate for wheel wear.

Rotation Switches for Conveyor Systems

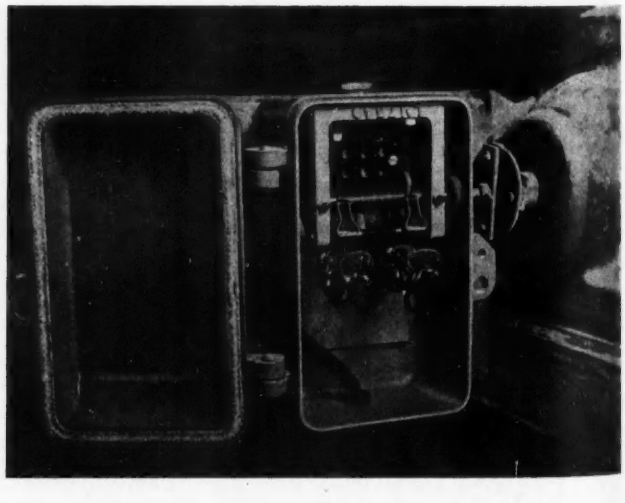
OUR illustration shows a rotation switch suitable for attachment to the layshaft of a conveyor and designed to operate if the shaft speed falls below a given value. In the installation here illustrated the rotation switch is coupled to the layshaft of a conveyor at the Heysham works of Imperial Chemical Industries, Ltd.; the switch cover is shown in the open position and the guard over the coupling has been removed to show the method of connection to the shaft.

The switch is made by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, in two patterns—one for breaking circuit and the other for making circuit, in the event of the shaft stopping or rotating too slowly. The switch case measures 8¼in by 7in by 4$\frac{5}{16}$in and is made of aluminium alloy, with a hinged lid which is dustproof and weatherproof. Each case contains two mercury switches, either delayed-make or delayed-break, rated at 5A, 230V a.c., or 1A, 230V d.c. These switches are carried in separate cradles which are free to swing independently against light pressure, and they are moved by two diametrically opposed "Tufnol" cams mounted on a stainless steel camshaft. The camshaft projects through a felt packing gland in the side of the box and is coupled to the shaft, as shown, or to some other convenient take-off point on the conveyor. As the camshaft rotates with the conveyor shaft it tilts the mercury switches periodically. When the shaft speed falls the period during which the switches are stationary (open or closed, according to type) increases. Below a certain speed this period will exceed the delay period of the mercury switches and they will then make or break the circuit; the switches must remain in the make or break position for three to five seconds before they will operate.

Rotation switches of the kind described here are designed to operate satisfactorily at speeds of between 25 and 50 r.p.m., to suit the average conveyor layshaft or idler. They can be usefully applied, for example, to a series of conveyors by connecting a switch to a relay circuit controlling the motor of the preceding conveyor and by repeating this process for each conveyor in the series. Then, if any conveyor slows up or stops, the corresponding rotation switch will stop the preceding conveyor motor; each preceding stage will be stopped in turn and build-up of material will be prevented.



Duplex Grinding Machine for Clutch Discs



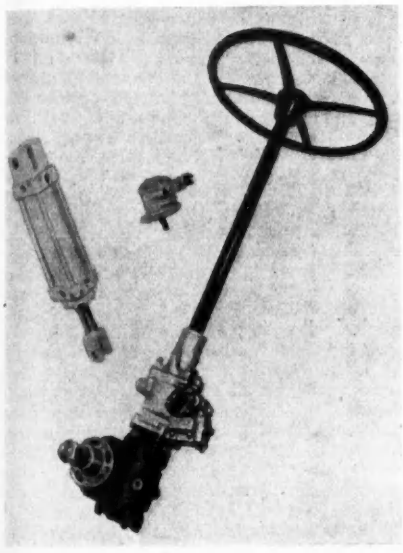
Weatherproof Rotation Switch (Cover Open) Coupled to Layshaft of a Conveyor

Hydraulically Assisted Steering

A HYDRAULICALLY assisted steering system is now being produced by Clayton Dewandre Company, Ltd., for public service vehicles and medium weight goods vehicles. It has been developed from the constant-flow system, as fitted to the Thornycroft "Antar" vehicle, but it incorporates a control valve of the reaction principle, so that the "feel" at the steering wheel reflects the resistance to steering encountered and is proportional to the assistance applied.

Power-assisted steering has in the past been used mainly for specialised heavy goods and military vehicles. Its use for a number of reasons is now considered desirable for the wider field of commercial vehicles and several chassis manufacturers are at present experimenting with power-assisted steering systems for public service vehicles and medium weight goods vehicles. The most obvious contribution claimed for power-assisted steering is towards safety. It enables the driver to retain control when the road wheels are subjected to severe shock from abnormal obstructions or should a tyre burst, and rough ground and soft or loose surfaces are more easily negotiated. Under ordinary circumstances driver fatigue is minimised and steering "kick" is eliminated, since the power cylinder absorbs the shocks otherwise transmitted to the steering wheel.

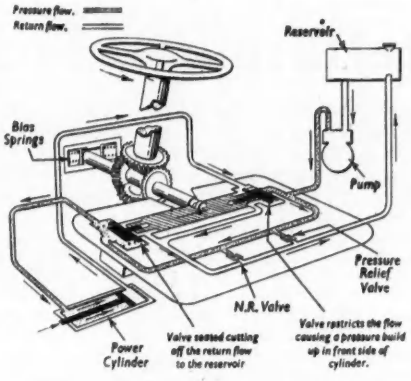
The system as diagrammatically illustrated herewith consists of a pump which draws fluid from the reservoir and circulates it through the steering control valve, which is integral with the steering column and forms an extension above the steering box. Connecting pipes from the



Components of Steering Assembly

valve lead to each end of the double-acting operating cylinder, which can be applied in any position between the steering wheel and the road wheels. The preferred position is as shown, with the cylinder coupled to the drop arm of the steering box, so that the power cylinder works in unison with the manual effort. Experience has shown that this gives the smoothest performance.

Bevel gears are interposed in the steering column shaft, causing a reversal of the direction of rotation, which reversal is corrected by using a worm gear in the steering box of opposite hand to that normally required. Bevel pinions are in mesh with the bevel gears splined to the column shaft and to the worm shaft of the steering box, the four gears being contained within a cage mounted on ball races. The shaft carrying the bevel pinions is extended at both ends, one end operating the reaction valves, whilst the other end acts against bias springs. The mechanism is arranged so that a non-assisted "feel" is experienced at the steering wheel at the low



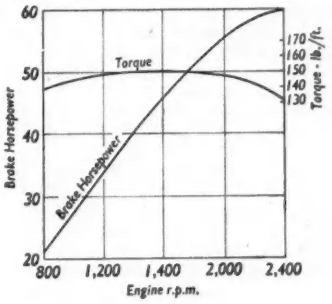
Schematic Working Diagram of Steering System

manual effort needed for slight corrections during straight ahead travel. This is achieved by arranging the bias spring preloading to hold the control valve in the neutral position so that below the designed steering effort there is no movement of the valve. This arrangement also helps to retain the normal self-centring of the steering wheels.

When the applied manual steering effort is sufficient to overcome the preloading of the bias springs, the valve operates to give power assistance. The diagram indicates how the reaction valves operate to interrupt the free flow of fluid from the pump with a resulting fluid pressure rise in one side of the power cylinder, which, combined with the driver's effort on the steering wheel, causes movement of the road wheels in the appropriate direction. Displaced fluid from the other side of the cylinder is returned to the reservoir. When the fluid pressure increases in the power circuit it reacts against the face of one of the reaction valves and an increased manual effort is required at the steering wheel to balance the forces on the valve. A pressure relief valve is incorporated in the control valve to limit the maximum pressure. Normal steering can still be effected when the pump is stationary, a non-return valve permitting fluid from the reservoir to be drawn into the power cylinder.

3·6-Litre Diesel Engine

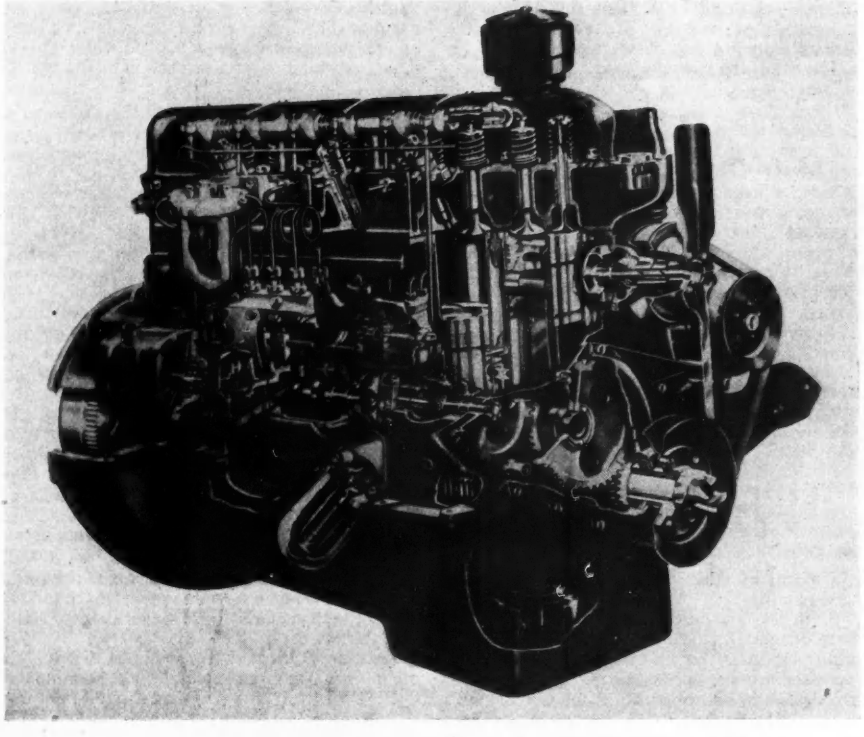
A FOUR-CYLINDER diesel engine of 3·61 litre capacity is now in production at the Dagenham works of the Ford Motor Company, Ltd. It has been designed as an alternative to the petrol engine for the 2 and 3-ton range of "Thames" commercial vehicles. The engine has a bore of 100mm, a stroke of 115mm, a compression ratio of 16 : 1, and at its governed speed of 2400 r.p.m. develops 60 b.h.p. As indicated on the power



Power Curves

curves, the maximum torque is 150 lb-ft at 1600 r.p.m., and it maintains over 140 lb-ft between 880 and 2200 r.p.m.

Other engine details include the use of a detachable cast iron cylinder head and wet cylinder liners. The crankshaft has induction hardened main and pin journals mounted from five 3in diameter bearings having thin-wall copper-lead liners. Its die cast, light alloy pistons are tin-plated, the combustion chamber is machined in the crown, and the gudgeon-pins are fully floating. Three compression rings and two oil control rings are fitted. In operation the engine valves are arranged to rotate. The fuel system of the engine includes a direct-injection pump with a pneumatic governor and four-hole injector nozzles are used. Fuel is drawn through a removable glass sediment bowl filter by the fuel lift pump and passes through a micronic paper element filter to the injection pump. A three-point engine mounting incorporates a hydraulic damper.



3·61 Litre, Four-Cylinder, O.H.V. Diesel Engine

Metallurgical Topics

Hardenability Measurements on Constructional Steels

A RECENT paper by H. Kiessler and K. Schweyher,[1] reporting determinations of the hardenability of various commercial constructional steels by end-quench tests, contains results of considerable interest which may be regarded as supplementary to the mass of information contained in the Iron and Steel Institute's Special Report[2] issued some years ago. Kiessler and Schweyer have carried out end-quench tests on fifteen different kinds of German commercial steels, three being carbon steels and twelve alloy steels. The results are given in a series of curves showing Rockwell C hardness at different distances (in millimetres) from the quenched face. In tests to ascertain the reproducibility of curves for the same steel from different parts of the same ingot, and from different ingots of the same cast, only small differences were found up to about 50mm from the quenched face. This agrees with the conclusions of the British investigators who, however, found rather bigger differences, probably owing to the larger number of examples that they examined. On the other hand, there were wide variations in the hardenability of different casts of steel produced to the same specification. These are largely explained by variations in composition within the range permitted by the specification. When direct comparison with British investigators' results is permissible, by reason of practical identity of composition, agreement appears to be close. Agreement is also apparent in the general character of the curves for each type of steel. For example, a number of chromium steels showed the peculiar "hump," observed by J. Glen, involving a rise in hardness of perhaps 3 R_c (about 30 on the Vickers diamond hardness scale) at about 1in to 1½in from the quenched end. This, however, quench assumes instantaneous cooling of the surface of the specimen to the temperature of the quenching medium and maintenance of that temperature throughout the quench. Again using Grossmann's curves, they deduced the critical diameter for H=2 (a strong water quench) and H=0·4 (a moderate oil-quench). These values, which were recorded in millimetres, are given in the table to the nearest 0·05in. The paper is illustrated by diagrams showing eighty-five Jominy curves on the fifteen types of steel, but this table probably affords the simplest means of comparing the German results with those of other investigators.

No regular relationship was found between the hardenability, measured by the end-quench test, and the McQuaid-Ehn grain size in the three types of steel (Ck 45, 37 MnSi 5 and 42 MnV 7) specially examined for this purpose.

REFERENCES

[1] *Archiv für das Eisenhüttenwesen*, November/December, 1953, page 475.

[2] "Symposium on the Hardenability of Steel," *Iron and Steel Institute Special Report No. 36.*

High-Temperature Protective Coatings

DR. A. H. SULLY, of the Fulmer Research Institute, has contributed an interesting article on "Special Coatings for Metals Used at High Temperatures" to a recent number of *Product Engineering*.* The high cost of special alloys to resist deformation at high temperatures, and at the same time to have adequate resistance to oxidation and corrosion, may often be avoided by the use of a steel of low alloy content with a suitably treated surface. Treatment may consist of surface impregnation with an element such as aluminium, silicon or chromium, which resists attack and which diffuses into the underlying metal or alloy; or of surface coating with a layer of non-porous material which does not diffuse into the metal, but gives protection by the formation of an impervious layer betweeen the metal and the atmosphere surrounding it; or of surface coating with material of low thermal emissivity (high reflectivity).

Mention is made of six methods of applying aluminium coatings including the continuous coating of steel strip by hot-dip aluminising. The steel must be protected from oxidation before it enters the aluminium bath, and steps are taken to minimise the formation of an intermediate brittle layer of an iron-aluminium compound. The rate of formation of this compound is reduced by the addition of silicon to the aluminium bath. Steel parts protected with an aluminised coating can be used for long periods at 700 deg. to 750 deg. Cent. and for shorter periods at higher temperatures. Two processes for siliconising the surface are described, the silicon being provided by the reduction of silicon tetrachloride. Siliconised coatings on ferrous materials confer resistance to concentrated and dilute acids and also offer protection against oxidation at moderately high temperatures. In this connection they may be used to protect highly oxidisable metals of high melting point, like molybdenum, from atmospheric attack at high temperatures. Modifications of the chromising process are discussed, each depending on a reaction at the surface between the steel and a chromium halide. As chromium forms a stable carbide, a low-carbon steel (or one in which the carbon is "fixed" by the addition of titanium) must be used to obtain depth of penetration, whereas the chromised surface is much harder and much shallower if the steel contains medium or high carbon. A thick coating, 0·25mm thick, is much more protective at temperatures above about 900 deg. Cent. than a coating only 0·1mm thick, because at such temperatures diffusion of the chromium reduces the chromium content of the surface and so lessens its resistance to corrosion. Coatings obtained by introducing halides of silicon and aluminium into the chromising atmosphere diffuse more slowly and give greater protection to ferrous alloys at temperatures up to 1000 deg. Cent.

High-temperature refractory coatings consist of a refractory, such as alumina or chromic oxide, together with a vitreous enamel type of composition of high softening temperature. To get good adhesion the coefficient of expansion of the coating must match that of the underlying metal. Coatings only 0·001in to 0·002in thick have been developed to give protection up to 975 deg. Cent.

In describing low-emissivity coatings, Dr. Sully necessarily refers to the work with which he has been associated at the Fulmer Institute, which has been mainly responsible for developments in this field. These coatings consist of refractory particles of low thermal emissivity (e.g. magnesia or alumina) bonded together with the minimum possible amount of a glassy matrix, and applied in such a thickness (usually about 0·006in) that radiation cannot be transmitted directly through the coating. With a source of heat at a temperature of from 1500 deg. to 2000 deg. Cent., from 60 to 75 per cent of the radiation which would be absorbed by an oxidised metal is reflected from the low-emissivity coating. A typical application would be to flame tubes of gas turbine engines, in which a considerable portion of the heat is transferred from the flame to the wall of the tube by radiation. In certain cases where flames of high luminosity are involved, the suppression of absorbed radiation may lead to the reduction in temperature of a coated gas turbine flame tube by about 225 deg. Cent. In general, low-emissivity coatings are not protective in the same sense as the refractory coatings referred to above. They rely, at least in part, on their porous structure to give the required low value of emissivity. If they are to be applied to alloys, such as mild steel, which are not themselves intrinsically resistant to oxidation, they must be applied to a surface already treated in such a way as to confer adequate

* *Product Engineering*, January, 1954, page 135.

Mean Chemical Composition of Steels Investigated and Critical Diameters Calculated from the End-Quench Hardness Curve

Type of steel	C, per cent	Si, per cent	Mn, per cent	Al, per cent	Cr, per cent	Mo, per cent	Ni, per cent	V, per cent	End-quenching temperature	Vickers diamond hardness*	Jominy distance, inches†	Ideal critical diameter, inches†	Critical diameters,†‡ inches	
										For 50 per cent martensite			H=2 (water)	H=0·4 (oil)
									Deg. Cent.					
Ck 35	0·35	0·25	0·55	—	—	—	—	—	850	400	0·20	1·42	1·05	0·4
Ck 45	0·45	0·25	0·65	—	—	—	—	—	830	440	0·24	1·70	1·25	0·55
Ck 60	0·60	0·25	0·65	—	—	—	—	—	810	520	0·28	1·97	1·45	0·7
40 Mn 4	0·40	0·35	0·95	—	—	—	—	—	830	420	0·31	2·17	1·75	0·9
30 Mn 5	0·30	0·25	1·35	—	—	—	—	—	840	370	0·47	2·83	2·5	1·4
VM 175	0·36	0·25	1·75	—	—	—	—	—	820	410	0·59	3·31	2·85	1·75
37 MnSi 5	0·37	1·25	1·25	—	—	—	—	—	850	410	0·53	3·07	2·7	1·55
42 MnV 7	0·42	0·25	1·75	—	—	—	—	0·10	850	430	0·67	3·50	3·05	1·95
34 CrAl 6	0·34	0·25	0·60	1·10	1·40	—	—	—	900	390	0·51	3·03	2·6	1·5
34 Cr 4	0·34	0·25	0·65	—	1·05	—	—	—	830	390	0·67	3·50	3·05	1·95
50 CrV 4	0·50	0·25	0·95	—	1·05	—	—	0·10	830	475	0·71	3·70	3·2	2·05
34 CrMo 4	0·34	0·25	0·65	—	1·05	0·20	—	—	850	390	0·79	3·94	3·45	2·25
24 CrMoV 55	0·24	0·25	0·45	—	1·35	0·55	—	0·20	970	350	1·10	4·81	4·35	3·05
30 CrV 9	0·30	0·30	0·60	—	2·35	—	—	0·15	850	430	>2·56	>7·13	>6·7	>5·3
VCN 35 w	0·23	0·25	0·60	—	0·75	—	3·50	—	830	—	2·56	7·09	6·5	5·3
VCN 35 h	0·32	0·25	0·60	—	0·75	—	3·50	—	830	470	>2·56	>7·13	>6·7	>5·3

* Approximate equivalents of Rockwell C hardness shown in diagrams. † Converted from millimetres. ‡ To nearest 0·05in.

resistance to oxidation, for example, to a chromised surface or to one covered by a thin layer of a protective refractory enamel.

This method of protection by low-emissivity coatings, for the development of which Dr. Sully himself has been largely responsible, should be of great value for components which, though not stressed so highly as to warrant the use of special materials, are exposed to intense radiation from a high-temperature source.

Die Castings

ONE of the outstanding aids to the production of small, lightly stressed components during the late war was the pressure die casting process; and the enormous increase in output of pressure die castings which occurred during that period has so widened experience of the process and extended the application of its products that it remains a manufacturing method of great importance in industry. Substantial books on "Die Casting," like those of H. H. Doehler (1951) and C. O. Herb (1952) bear witness to the increasing interest in the subject during recent years.

The process was well known and was the subject of many technical books and papers before the war, but was not so widely practised in this country as in America. The extension of its use was aided through the formation, by the Ministry of Supply, of the Production Advisory Committee (Die Castings), which was able to render technical aid in promoting efficient and economic use of die castings, and in maintaining as high a standard of quality as possible. This Advisory Committee still exists and, in collaboration with its members, Mr. F. D. Penny has produced a monograph on die castings, which supplies thoroughly up to date and practical information on the subject.*

In the first chapter, after preliminary definitions, the advantages and limitations of die casting are very fairly stated. The use of die castings eliminates much, if not all, machining and thus economises labour and materials. It allows castings of small wall thickness and complicated form to be produced when these could be made only with difficulty by other means. Limitations are the relatively high cost of dies, which renders the process uneconomical unless a very large number of separate castings are required. On the materials side, there is the possibility of unsoundness or porosity in the casting, together with the comparative brittleness of some of the alloys available for die casting. These limitations affecting the material call for the closest attention to design and most careful selection of the alloys used. Both these aspects of the subject are fully dealt with; but first comes a description of the different systems of pressure die casting, the various kinds of dies used both for pressure and gravity die casting, and the material of the dies. These sections are profusely illustrated with diagrams and photographs. The choice of alloys is then considered and an account is given of the comparative merits, for pressure die castings, of zinc, aluminium and magnesium alloys, none of which is in the exclusive possession of all the advantages. Nevertheless, in output, zinc alloys are well ahead of the others and their low melting point, high fluidity, good machinability, inherent corrosion resistance and ease with which they can be protected against more corrosive conditions, all favour their use. Brass and aluminium bronze are alloys of greater strength and toughness; but, owing to their high melting point and the consequent rapid deterioration of the dies, they are unsuitable for the pressure die casting process though they are often used for gravity die castings. In the gravity process a high melting point is less restrictive and even cast iron is die cast on a large scale in mechanised assemblies. Owing to the chilling effect of the mould, iron die castings must be annealed to remove brittleness and render them machinable.

Bound up with the choice of an alloy is the design of die castings, to which the next chapter is devoted. This is a matter of the highest importance in obtaining satisfactory results; and, although it is dealt with in considerable detail, it is not intended to obviate consultation with a die casting engineer, with whom collaboration is advised in the design of all but the simplest components. The final chapter deals with Service methods of inspection of die castings, and tables are appended of composition, mechanical properties, corrosion resistance, dimensional tolerances, &c., of die casting alloys.

Though primarily intended for the benefit of the Services, this handbook will serve admirably to meet the requirements of industry and should be of great value to all concerned, whether as designers, manufacturers or users of die cast products.

* *A Handbook on Die Castings*, by F. D. Penny. London: Her Majesty's Stationery Office. 1953. Price 6s.

Bolts for High-Temperature Service

BOLTS for use at high temperatures in steam and gas turbines, turbo-jets and atomic power plants are highly specialised both in their engineering and metallurgical aspects. Fracture of bolts during operation may lead to disastrous results. The manufacture and characteristics of high-temperature bolts are discussed by T. W. Harker,* who emphasises the importance of (1) an ample margin of safety as a precaution not only against yielding when the initial tightening torque is applied, but especially against creep and fatigue which are accelerated at elevated temperatures; and (2) resistance to oxidation and corrosion. Apart from questions of design, difficulties arise in production because every increase in strength at high temperatures makes the material harder to forge and to machine. One of two methods of manufacture is commonly employed—either machining from hexagonal bar, or upsetting the bolt-head from round bar of about the same diameter as the shank. Threads may be either cut or rolled, but preferably rolled so that the fibre of the material follows the contour of the threads. Also, when the threads are cut instead of rolled, they may have a torn surface increasing the tendency to gall at elevated temperatures. Machining of the complete bolt is too costly an operation for mass production, and therefore some method of upsetting the head is used: either cold upsetting, carried out at room temperature, or warm working at a raised temperature below that of recrystallisation, or hot forging at a temperature above the recrystallisation temperature. Cold heading may offer great difficulty on account of the high yield strength of this type of material and its rapid rate of work-hardening. Hot forging may be carried out at temperatures as high as 1250 deg. Cent. but the maximum temperature used for any particular alloy must be closely controlled to avoid burning. Warm working is a special treatment, suitable for some materials, and must be carried out at a carefully selected temperature to obtain the best properties.

Some creep characteristics of a number of commonly used high-temperature alloys are recorded. Of these, Inconel X shows outstanding 10,000-hour rupture stress at temperatures up to 750 deg. Cent., followed at a considerable interval by 16 : 25 : 6 chromium-nickel-molybdenum steel. Next come 18 : 8 chromium-nickel with 2 to 3 per cent of molybdenum, 25 : 20 and 25 : 12 chromium-nickel, and ordinary 18 : 8 chromium-nickel. The iron-base material, Discaloy, falls between Inconel X (a nickel-chromium precipitation-hardening alloy) and the 16 : 25 : 6 alloy. The same order is preserved at lower temperatures, for example, at 650 deg. and 550 deg. Cent., at which steels of lower alloy content show useful strength. Proper heat treatment is extremely important: in precipitation-hardening alloys to give the best properties and in cold worked material to reduce residual stresses without appreciable decrease in hardness.

Like all materials for use at high temperatures, high-temperature bolting must be a compromise between the properties of the metals available and the designer's requirements. Producers are faced with the problem of developing the most economical methods of manufacturing that will at the same time speed up production and save material. So far, in the opinion of the author, who is metallurgist in the Aero Division, H. M. Harper Co., Illinois, cold heading has proved to be the most economical method for shop use. Nevertheless, operations that are performed hot require less power than equivalent deformation performed cold, and with some alloys hot working is the only method of upsetting without fracturing the metal in the process.

* *Metal Progress*, October 1953, page 125.

Wear Tests on Normalised Steels

WEAR tests for the determination of resistance to abrasion take many forms and are difficult to interpret accurately. Nevertheless, it is generally agreed that, provided the testing conditions remain constant and the microstructures of the materials tested are comparable, wear shown by a steel tends to decrease as the carbon content increases. This effect is relatively the same for all types of microstructure, though actual wear progressively decreases as pearlite becomes finer, and is much less for steels in the martensitic condition. The effect of alloy elements on the wear of steel is not so easy to define, as their influence may be exercised indirectly through their effect on the constitution of the carbides or on the structure and relative amount of the pearlite. The influence of manganese, nickel and vanadium, in the presence of carbon, on the wear resistance of normalised steels has been studied by H. Arend.[1] He has carried out tests in the Spindel wear-testing machine on thirty-three normalised steels containing about 0·07 to 1·08 per cent of carbon, with vanadium up to 4·8 per cent, manganese to 6·5 per cent, and nickel to 3·8 per cent, with the addition of two austenitic steels, manganese 10 per cent and nickel 20 per cent. The Spindel machine[2] in its original form consists of a rotating disc, 1mm thick and 320mm diameter, made of hard steel, against which the specimen is held under a steady pressure. The machine can be run at different speeds and the wear is measured by the length of the segment ground away in the specimen. In a modification of the machine a disc 8mm thick is used, and wear measured by loss of weight. Both forms of test were employed by Arend, who found that, provided the steels were in the same state of heat treatment (i.e. normalised), the carbon content had the predominant influence on the amount of wear. In the vanadium steels, however, it was not the total carbon but that part of it not bound to the vanadium as V_4C_3 which determined the amount of abrasion: in other words, the wear resistance increased with cementite content. Comparison of the wear of the manganese and the nickel steels of the same carbon content showed that manganese was more effective in reducing abrasion, and this applied also to the austenitic steels examined. Results were correlated with Brinell hardness numbers, and it was found that up to a hardness of 300 there was a reduction of wear with increase in hardness of the steel after which it remained approximately constant. Whereas with hardness at and above 300, the advantage lay with vanadium steels, manganese steels behaved more favourably at hardnesses below 300. Esser and Arend[3] had previously found that with the wide-faced discs moving at 1m/sec., the wear of 0·3–0·75 per cent carbon steel was independent of the pressure applied. Arend's recent experiments confirm that wear is almost independent of surface pressure between 4kg and 15kg per square millimetre at speeds of about 1m/sec. An increase in speed beyond 1·4m/sec. to 2m/sec. led to a great increase in abrasion at pressures of about 10kg per square millimetre.

REFERENCES

[1] *Archiv für das Eisenhüttenwesen*, November/December, 1953, page 529.

[2] *Zeit. V.D.I.*, 1926, Vol. 70, page 415; *The Metallurgist*, June 25, 1926, page 83; Experimental Work With the Spindel Machine, by Eiländer, Köster and others, is reported in *Archiv für das Eisenhüttenwesen*, 1934, August, page 61, and September, page 111.

[3] *Archiv für das Eisenhüttenwesen*, August, 1941, Vol. 15, page 103.

CORROSION AND ITS PREVENTION.—The Department of Metallurgy at the Battersea Polytechnic, Battersea Park Road, London, S.W.11, announces a summer school on "The Fundamentals of Corrosion and its Prevention." It will be held from July 20th to 23rd, and eight lectures are to be given by Mr. S. C. Britton, Dr. T. P. Hoar and Dr. L. L. Shrein. The Battersea Polytechnic says that it is desirable that intending students should have attained intermediate B.Sc. standard in chemistry and physics.

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FIGHTING SERVICES' ESTIMATES, 1954

The Estimates for the Fighting Services, published last week, give little indication that revolutionary weapons now in production have yet had any marked effect on the build-up of our Armed Forces or on our defence strategy. Not only is the total budget for each Service approximately the same as for 1953–54, but most of the various items of expenditure are also within a small percentage of the current year's estimate. Differences in the amount of U.S. aid allocated to the three Services complicate comparisons, but, including aid, the Royal Air Force budget of £537 million is, in fact, £11,000,000 less than the sum estimated for 1953–54, despite the provision made for atomic bombs and for the first deliveries of "Valiant" medium bombers "capable of using them to the fullest possible extent." In his accompanying memorandum the Secretary of State for Air announces that first supplies of guided missiles will be issued to piloted fighters and will eventually entirely replace aircraft cannon. Surface-to-air guided missiles, to be issued later, will supplement but not supplant piloted aircraft. Promise is made of large deliveries during the coming year of "Swifts" and "Hunters" to Fighter Command—which now has its first swept-wing fighters, though no mention is made of the formation of a "Swift" squadron promised for the end of 1953. Equally satisfactory is the marked improvement in the efficiency of our radar control for interceptor fighters and also the general speed-up in the whole of our ground organisation to deal with the supersonic speeds of modern aircraft. The expansion of Coastal Command continues and the re-equipment of the Second Tactical Air Force with "Vampires" is now nearly complete. This force has already its full complement of "Sabre" fighter/interceptors received from Canada and the United States.

The Army Estimates, including U.S. aid, total £561 million—£20,000,000 less than for the current year, due mainly to a reduction of £14,000,000 for guns and ammunition and to a decline in manpower of some 13,000 men. The Secretary of State for War confirms the general belief that British military opinion prefers the ground-to-ground missile to the U.S. atomic gun as the Army's offensive weapon. He adds that fissile material is likely to be in short supply for a long time to come and in the surface-to-surface guided missile it can develop the highest proportion of its atomic power. The new missile will be handled by the artillery and not by the R.A.F. Meanwhile training has gone ahead in methods of protection and detection and a close study has been made of the problems of supply, movement and communications under atomic attack and of the tactical and strategical use of atomic weapons. Concurrently, much progress has been made in the improvement of conventional weapons and equipment. A new heavy gun tank is to be tried out in Germany during the coming year, and now that the Regular Army has adequate numbers of Centurion tanks—the best tank of its size in service to-day—we are fortunate in being able to maintain our production potential by their sale to foreign countries. Other improved weapons include a light anti-aircraft gun with a fast power traverse, for defence against low-flying aircraft; a lighter and more powerful 120mm recoilless anti-tank gun to replace the old 17-pounder; the replacement of the Sten gun by the new submachine gun known as the Patchett; and the now general use of the Energa grenade and the 3·5in rocket-launcher. Five thousand Belgian F.N. rifles, recently adopted in preference to the British E.M.2, have been ordered for trial in all theatres. River crossing equipment is to be improved by a heavy girder bridge now in production, by the new Light Assault Floating Bridge, Class 30, and by the Heavy Ferry, Class 80.

The Navy Estimates, at £367 million, including £14,000,000 U.S. aid, show an increase of £2,500,000 over the current year's estimate. A year ago the First Lord warned the nation that our fleet is getting old and that a speedy replacement programme by new construction is vital if the Royal Navy is to exist as an efficient and balanced fighting force. But there are still no signs of the programme. Emphasis remains "on the expansion of our minesweeper and anti-submarine forces and on completing carriers under construction." In this connection it is much to be regretted that the Navy Estimates are presented in a form which gives little idea of the very considerable effort we are making on behalf of N.A.T.O. The completion in the coming year of three carriers laid down in the war may, as the First Lord states, provide a notable accession of strength to the Royal Navy. But it is not much to boast about when we have at the present time only one carrier capable of operating modern jet aircraft. Nor is British sea power made any more impressive by the inclusion among vessels "in course of construction" of two carriers on which no work has been done since 1946. If public interest is to be maintained in the Navy—and suitable lads are to be encouraged to join it—it would be wiser to stress that, temporarily, we are having to concentrate on N.A.T.O.'s urgent naval needs. We have under construction or completed no less than 150 coastal and inshore minesweepers, these small, relatively slow vessels costing an average of £300,000 each—only £50,000 less than the price of a powerful 36-knot, 1500-ton destroyer-leader in 1937. Also under construction are twenty-five new fast frigates, several frigates converted from destroyers, and numbers of seaward defence vessels and fast patrol vessels. Even a little seaward defence vessel, with a crew of less than twenty, costs £176,000! Comparisons with pre-war costs are even more striking in the case of large vessels. The light fleet carrier "Centaur" (completed except for the angled deck) cost £10,500,000, compared with £3·3 million for the "Ark Royal" (sunk during the war), and £1·8 million for a "Dreadnought" battleship. New items of interest are the launch at Vickers-Armstrong's yard at Barrow of a submarine, the "Explorer," and mention of the main armament of 4in to 6in guns for the "Tiger" and "Blake,"—two of the three cruisers of the "Defence" class on which constructional work is still suspended. The latter indicates that we have not only produced a much more powerful and effective 6in gun, but that ample deck space remains for an additional armament of guided rockets, if required.

ENGINEERING AND SHIPBUILDING WAGES

The Courts of Inquiry which were set up by the Minister of Labour to examine the wage disputes in the engineering and shipbuilding industries have performed their somewhat complicated task expeditiously. The two courts, each composed of the same members under the chairmanship of Lord Justice Morris, were appointed on New Year's Day, and their reports were presented to Parliament last Friday. Thus, in just under two months the courts have heard a mass of evidence, have examined many figures, have considered the arguments for and against a 15 per cent increase in the

wages of adult male workers in both industries, and have formulated some recommendations which may assist the resumption of negotiations between the employers' federations and the unions. Although there are two reports, one for engineering and the other for shipbuilding, the conclusions and recommendations presented in each of them are similar. The foremost of these recommendations is that the parties should "resume negotiations with a view to agreeing to some increase," the suggestion of the courts being that such an increase might be "something in the region of one-third of the amount claimed." That would be 5 per cent—instead of the 15 per cent originally demanded—which, computed on existing minimum time rates in both industries, would represent an increase of approximately 7s. a week for skilled men and rather less than 6s. a week for unskilled men.

Before putting forward this suggestion, the Courts of Inquiry have set out in their reports some of the factors which, in their judgment, need to be taken into account in assessing the merits of wage claims. They say, for example, that "in the case of the lower wage earning groups the effect of a material rise in the cost of living is one to which great heed must be paid." They also comment on productivity and upon wages in other industries, saying on the latter point that while "no exact comparisons can be made between one industry and another, wage rates in other industries cannot be ignored and may indeed provide some guide, though not the only one." After consideration of such matters as these, the courts have deduced that although average earnings are relatively high in the engineering and shipbuilding industries, many workers earn less than the average. The conclusion is then reached that the minimum rates for unskilled work are definitely low when compared with those ruling in several other of the country's main industries. Both reports rightly emphasise, however, the obvious dangers to the national economy at the present time of a substantial increase in production costs. It was, of course, the cost factor more than any other which led to the rejection by the Engineering and Allied Employers' National Federation and the Shipbuilding Employers' Federation of the claim for a 15 per cent wage increase put forward by the Confederation of Shipbuilding and Engineering Unions. The employers' federations have given facts and figures which show that orders, and especially orders from overseas, are not being secured so readily as they were. The growing intensity of foreign competition compels this country to quote the best possible prices for its products, and anything which adds to present manufacturing costs is bound to hinder still further the filling up of diminishing order books in the engineering and shipbuilding industries. That is a situation which the unions do not appear to have appreciated fully ; it is a situation which has not changed materially while the Courts of Inquiry have been deliberating. The courts agree that they found it impossible "to generalise as to the effect of a wage increase on the export trade," though they acknowledge that "any appreciable rise in costs, if it could not be met out of profits, would have a material effect on that trade." In that context, the observations of the courts on the subject of profits deserve careful study. It has been urged repeatedly by the unions that a profitable industry can afford to meet wage claims generously. In industries like engineering and shipbuilding, however, the place of reserves, or "retained" profits as the reports call them, must be properly understood. Their function is the maintenance and improvement of a business —no small matter in these days—and in fulfilling that function they undoubtedly benefit the people employed, even though, at first sight, the benefit may appear to be a long-term one. But after studying all these arguments, which amount to little more than a summary of what the two sides said, the reader of the reports is likely, we think, to conclude that the findings are hardly based upon them at all ! It seems much more probable that the courts were influenced, in making a suggestion for a 5 per cent increase, by the fact that increases of about 7s. per week are bringing agreement in other industries.

There are two recommendations in the reports which break some fresh ground. Comment is made about the recurring occasions in recent years on which there have been wage negotiations in the engineering industry, as a result of union demands. In the opinion of the courts, these negotiations have generally been "hard and protracted," and there is a suggestion that the establishment of some formal machinery for the negotiation of wage settlements in the industry would be valuable. A Court of Inquiry which investigated a wage dispute in 1948 recommended a simplification of the engineering wages structure and some preliminary steps to that end were taken. But the wage claims which have been made almost every year since then have prevented further progress with a new wages structure, and it is possible that the present courts' suggestion can give fresh impetus to a matter that is long overdue. The other recommendation, included in both reports, is a little obscure. In the course of their inquiries, the courts felt that some of the issues raised were "essentially part of much wider problems affecting the national economy." They therefore think that a solution of those "wider problems" would be more readily reached if an "authoritative and impartial body" was appointed to consider them and to give advice and guidance as to broad policy and possible action. Without further amplification of this suggestion, it is not easy to see just how useful such an "authoritative and impartial body" could be in wage negotiations. The organisation of this country's industries, and certainly of its engineering and shipbuilding industries, enables them to determine how they stand in relation to the national economy. In the resumed negotiations on engineering and shipbuilding wages, which it may be hoped will result from the publication of the reports, full weight will no doubt be given to the economic factors which both sides must keep in mind in their endeavours to reach a satisfactory settlement. For that the industry should continue to be prosperous and profitable is as much to the advantage of employees as it is to that of employers, shareholders and the nation at large.

Guerilla Strikes

(Contributed)

THERE is extant a letter written by James Watt on October 31, 1780, in which, complaining of the growing threat to the patent for the separate condenser, he tells Matthew Boulton that :

"We are in the state of the old Roman who was found guilty of raising better crops than his neighbour, and was therefore ordered to bring before the assembly of the people his instruments of husbandry, and to tell them of his art. He complied, and when he had done, said : 'These, O Romans, are the instruments of our art ; but I cannot bring into the forum the labours, the sweats, the watchings, the anxieties, the cares, which produced these crops.' "

The words take us back to the very dawn of industry and remind us of our indebtedness, here in Great Britain, to those who, like Watt and many others, laboured to create the foundations of our industry. While the industrial clock was wound up at the outset by the efforts, mental and physical, of innumerable gifted and hard-working men, it has to be kept wound up by the persistence of such efforts. This need is inescapable and just as a clock will come to a stop unless it is wound up, so also must an industrial nation. Vital, indeed, at the present time, is the need that the British industrial clock shall be kept wound up, and it can only be done by the united efforts of all those concerned in industry.

Not only must the clock be kept wound. It must not be tinkered with. Tinkering with the clock is a stupid procedure even when it is only the clock on the kitchen mantelpiece. Tinkering with the national industrial clock is in quite a different category, since it puts at hazard the very life and liberty of the nation. We have been witnessing, recently, the squalid operation of tinkering with industry by means of what are called "guerilla" tactics, a word signifying a type of warfare akin to brigandage. It is not a British word, nor does it suggest anything British in principle. "Strike" is an Anglo-Saxon word which ought never to be joined to such an alien word as "guerilla." A strike is something which we associate with the inalienable liberty of men to withhold their labour in the face of manifest injustice. The "guerilla" strike—as implied by its very name—is a disreputable instrument, the use of which offers an affront to freedom as well as being an admission of inferiority on the part of those who use it. Trade unions are so essential a part of our national organisation and are the product of such vast industrial experience that they will not tolerate procedures which threaten to disrupt not only the fabric of trade unionism, but to put at hazard the livelihood and well-being of its members and, indeed, of all citizens. This is particularly the case at a time when the very life of the country and of the Commonwealth depends on the preservation of its industry in the face of strong and increasing competition from other industrial nations.

It is no exaggeration to state that the good will and strenuous efforts of every fit citizen are required if we—and here we have in mind the British engineering and shipbuilding industries in all their branches—are to maintain, let alone enhance, what is called the standard of living. There is no longer any use for fanatics of the right or of the left. Only the highest standard of trade union leadership co-operating with the highest quality of commercial and technical management can suffice to bring us through

the years immediately ahead. Thought, not talk, is requisite and we need to be reminded, constantly, that a main ingredient in human failure is talkativeness. It is among the diseases of democracy, and is the fomenter of immeasurable trouble. Specially to be guarded against by trade unionists—or any other citizens—is the assumption of leadership by talkative fanatics who—as remarked by Dr. Johnson—" weave their sophistry till their own reason is entangled."

In his admirable Calvin W. Rice Lecture, delivered in 1952, L. F. Urwick relates how Frederick Winslow Taylor, toward the end of his life, laid down two basic conditions " without which scientific management cannot be said to exist in any establishment." First of these two conditions he placed the development of a common purpose—" both sides take their eyes off the division of the surplus as the all-important matter, and together turn their attention toward increasing the size of the surplus." There is another type of investigation, wrote Taylor, " which should receive special attention, namely, the accurate study of the motives which influence men." While the ideas of Frederick Winslow Taylor provoked acute criticism among the leaders of organised labour, " it remains a fact of record, which should not be forgotten, that there never was a strike in any plant where he himself was operating." Let us ever keep in mind the certainty that there is no human influence so beneficent as the influence of Peace. It is not to be regarded as a mere inactivity, but as an activity possessing incomparable power of bringing blessings and benefits to all who pursue it. In the light shed by a mutual desire for Peace all disputes are soluble and " guerilla " tactics are seen for the barbarism which they are. Finally, let us all commit not only to memory but to life, the splendid words which Shakespeare puts into the mouth of the Archbishop :

> " A peace is of the nature of a conquest;
> For then both parties nobly are subdu'd,
> And neither party loser."

Presidents' Gallery at the " Mechanicals "

AT the Institution of Mechanical Engineers a passage leads off the entrance hall behind the dais of the lecture theatre. This passage, two rooms that open off it and another room at its end have all recently been rearranged, redecorated and refurnished, under the direction of the Institution's architect, Mr. Ernest Ruthen, and under the advice of Sir Hugh Casson, as a part of the extensive reconstruction and improvement of the building that has been going on since the Institution acquired the freehold in 1952. The passage is now named " The Presidents' Gallery." It carries on its walls framed photographs of past-presidents of the Institution. The two rooms that open off it have been named respectively the " James Watt " room and the " George Stephenson " room, and in each are arranged valuable mementoes of those two great engineers. The room at the end of the gallery has been arranged for the special use of the President during his year of office.

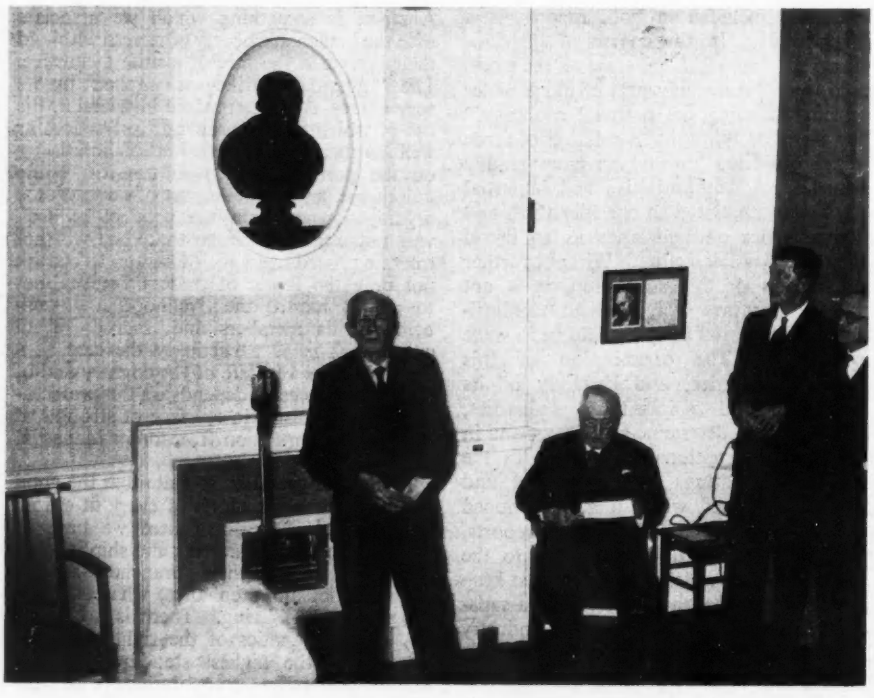
Last Friday, just before the presentation of the Clayton lecture by Sir Christopher Hinton, which we begin to print on another page, there was an official opening ceremony. It was performed by Dr. Adrian, President of the Royal Society. He first unveiled a bronze bust of James Watt which has just been presented to the Institution by Mr. Nelson Haden and which stands in a niche in the " James Watt " room. In doing so he remarked that if a monument was required for James Watt they should look beyond the room and beyond the impressive building of the Mechanical Engineers to the whole of the modern world outside, for if there was one man more than another who helped to establish the modern scientific age it was the man who gave it the power of steam. But Watt did more than improve an engine ; by doing it he showed how new discoveries in physical science could be harnessed for daily use. No field of manufacture lay outside his fertile ingenuity. The famous partnership of Boulton and Watt led in the whole advance of industrial technique. James Watt was not only the foremost engineer of his day. He also found the time to be a brilliant chemist, a worthy companion of Priestley and Keir in the Lunar Society of Birmingham, and was one of the first to appreciate the true nature of water as a compound of oxygen and hydrogen. He was elected a Fellow of the Royal Society in 1785 on a certificate signed by the leading scientists of that time. In 1843 his son, James Watt the younger, presented the Society with a marble bust copied from Chantrey's original by the chief assistant in his studio, James Heffernan. It was a bronze replica of that bust which stood there to-day, and there was no place where it deserved greater honour.

Dr. Adrian then formally declared the new range of rooms open.

The President, Mr. Roebuck, then asked Mr. Nelson Haden, whose forbears had associations with James Watt himself, to express their thanks to Dr. Adrian.

Mr. Nelson Haden said that no doubt this pleasant duty had been given him in order that he might thank Dr. Adrian personally and, through him, the Council of the Royal Society for their kindness in lending him the marble bust from which the copy had been made. His kindness in this and, it should be added, the skill of the foundrymen of the Morris Singer Company enabled him to gratify a wish and to fulfil an obligation. James Watt was the kindly master of his great-great-grandfather, who, among other services to Watt, was the superintendent of the Copying Machine Company at Handsworth. They must, he thought, have had a happy relationship, for in his old age Watt remembered him in his will with a small legacy. His son, the speaker's great-grandfather, was apprenticed to Boulton and Watt and became one of their chief erectors. He installed the pumping engines at Cranston Hill, Glasgow, and many mill engines in the West of England, and he also erected the first municipal gasworks at Leeds. He put the two 4 h.p. paddle engines at right angles into the " Princess Charlotte " and coupled them with Watt's permission. Then he was given Boulton and Watt's agency in the West of England, and on the strength of it in 1816 he founded the company which bore his name and the speaker's. In the same year he went back to Birmingham and married Ann Nelson, who was the companion housekeeper to Mrs. Watt, jun., so that he (the speaker) owed a great debt of gratitude to James Watt. He wanted to express a double indebtedness to Watt and to the Institution by finding a bust which might be a focus and an inspiration in the James Watt room, and Dr. Adrian had helped him to do so.

The accompanying illustration shows the James Watt room.



Dr. E. D. Adrian, President of the Roya Society, after Unveiling the Bust of James Watt, Opened the New Suite of Rooms at the " Mechanicals "

Books Received

Information Theory. By S. Goldman. London : Constable and Co., Ltd., 10, Orange Street, W.C.2. Price 50s.

Grading of Clerical Work. Published by the Office Management Association, 8, Hill Street, W.1. Price 21s.

Welding Engineering. By B. E. Rossi. London : McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, E.C.4. Price 64s.

Gears for Small Mechanisms. By W. O. Davis. London : N.A.G. Press, Ltd., 226, Latymer Court, Hammersmith, W.6. Price 25s.

The Electrical Year Book, 1954. Published in Manchester by Emmott and Co., Ltd., 31, King Street West, Manchester, 3. Price 3s.

Applied Heat and Heat Engines. By L. Pilborough. London : Butterworths Scientific Publications, Ltd., 88, Kingsway, W.C.2. Price 35s.

Applied Elasticity. By Chi-Teh Wang. London : McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, E.C.4. Price 57s. 6d.

The Control of Quality in the Production of Wrought Non-Ferrous Metals and Alloys. Symposium held in London on the occasion of the annual general meeting of the Institute of Metals. London : The Institute of Metals, 4, Grosvenor Gardens, S.W.1. Price 15s.

Nuclear Reactors and Power Production

By SIR CHRISTOPHER HINTON, M.A.*

No. I

This "James Clayton" Lecture, presented before the Institution of Mechanical Engineers on Friday, February 26th, deals with the design and construction of nuclear reactors, and particularly of types suitable for the generation of power. A detailed description is given of the British Experimental Pile (BEPO) at Harwell. There follows an account of some of the engineering and construction problems met in the erection of the Windscale piles, and the solutions achieved. The problems involved in designing power-producing reactors are discussed. The possible reactors may be divided into two groups: those which use "thermal" neutrons and are similar in principle to BEPO, and those which use "intermediate" or "fast" neutrons and have a much smaller core size. Within each group are alternatives provided by differences in fuel, moderator, and coolant. A number of these are reviewed, and prospects for the large-scale development of nuclear power are discussed.

The British Experimental Pile (BEPO).—The first nuclear reactor of any size to be built in Great Britain was the British Experimental Pile (BEPO), which was built at Harwell and completed in the first half of 1948.

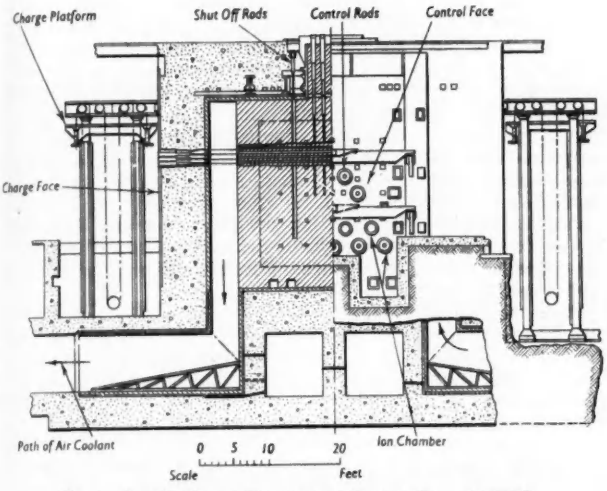


Fig. 1—Part-Sectioned Elevation of Control Face of BEPO

At the outset, a choice had to be made between graphite and heavy water for the moderator. These were the only two suitable materials for a natural uranium reactor for which the necessary information was available. Heavy water had been employed by the Canadians in their NRX reactor at Chalk River, but production was confined to two plants: an American owned plant in Canada and the Norsk Hydro plant in Norway; it seemed that it would be difficult, if not impossible, to secure an adequate supply. BEPO was, among other things, to provide information for the design of the large production piles, and it was known that heavy water would not be available for these. It was therefore decided to build a graphite-moderated, air-cooled pile inside an existing R.A.F. hangar at Harwell. Work on the site started in 1946. The central portion of the hangar roof had to be raised to allow for the necessary clearances. The general arrangement of the reactor is shown in Fig. 1. The main structure comprises a graphite core, resting on concrete foundations and surrounded by the main concrete shield and associated steelwork. The graphite is stacked in the form of a 26ft cube, built of 28,000 blocks. The standard dimensions of the blocks are 7¼in by 7¼in by 29in, but, allowing for all minor variations in shape, there are nearly 1500 different types. The blocks rested on the central concrete plinth of the foundation on the top of which a steel floor was laid, which partly protects the concrete from neutron irradiation. This steel floor was levelled to an accuracy of ±0·010in. The blocks were machined in a special workshop and stacked inside the concrete shield after it had been finished and cleaned; admission to the vault was through air locks and it was kept under a slight positive pressure with filtered air. This scrupulous cleanliness was needed because dirt might contain substances which would absorb neutrons. The graphite structure was built to the correct height within ±0·015in by carefully selecting over and under-sized blocks, which had an individual tolerance of ±0·0025in. It contains 1760 horizontal channels, on a 7¼in square pitch, but the central 888 channels only are loaded with uranium, forming a cylindrical reacting core 20ft long by 20ft in diameter. The remaining 3ft thickness of graphite acts as a neutron reflector. The general form of the graphite structure is shown in Fig. 2.

The main shield comprises a "biological shield" of reinforced concrete 6ft 6in thick at the sides, and an inner "thermal shield" made of 6in steel plates. The purpose of the thermal shield is to protect the inner face of the concrete from overheating by absorption of thermal neutrons. For the biological shield, special concrete using a barytes aggregate was used, having a specific gravity of about 3·5 compared with the usual figure of 2·5 for ordinary concrete. The use of barytes was an emergency decision compelled by the discovery at Chalk River that neutron absorption in iron was followed by the emission of a more penetrating gamma-ray than had previously been supposed.

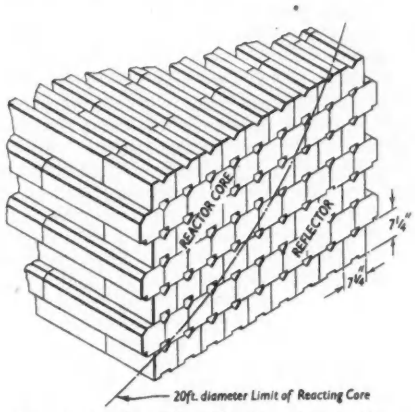


Fig. 2—Details of Graphite Core Construction (BEPO)

In casting the concrete, the steel thermal shielding on its inner face and a casing of boiler plate on its outer face were used as permanent shuttering. They were supported on structural steelwork. The reason for adopting this procedure was that holes through the biological shielding had to

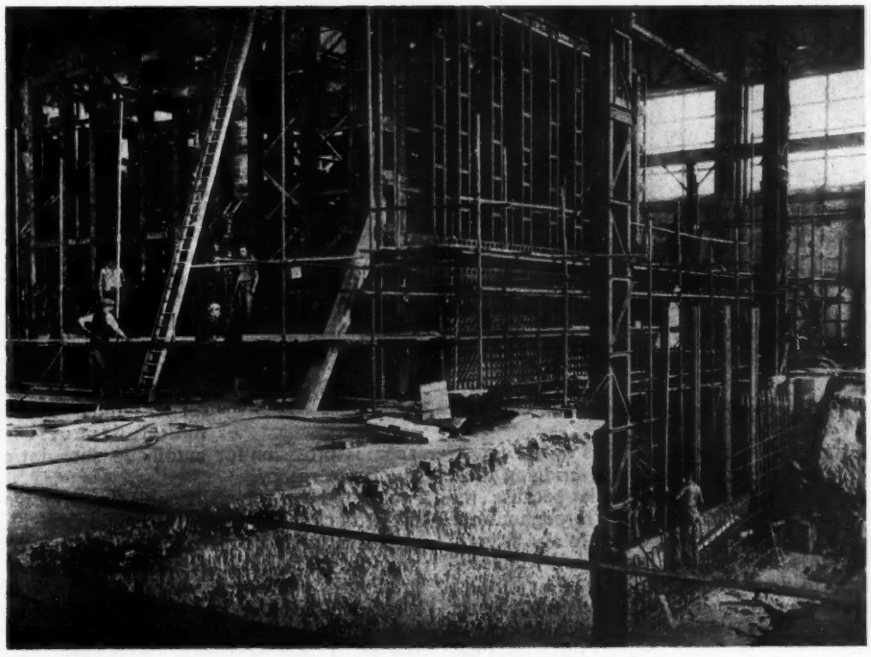


Fig. 3—Permanent Shuttering System

* Deputy Controller of Atomic Energy (Production), Risley, Lancs.

register accurately with holes in the graphite. This accuracy was best achieved by locating the cores for the holes in a permanent structural shuttering system (Fig. 3). Fig. 4 shows a general view during construction of BEPO.

In the charge and discharge faces, tubes had to be cast into the concrete opposite every hole in the graphite lattice, and these tubes were supported in an egg-box structure of steelwork which was cast into the wall. When the pile is operating these tubes are closed by plugs made of steel tubes filled with concrete.

Extensions of the graphite, known as "thermal columns," are made through holes in the top and side shields to enable powerful sources of thermal neutrons to be available for experimental purposes. These columns are normally covered by special shielding.

Between these charge and discharge walls and the face of the graphite there are gaps 4ft wide, as shown in Fig. 5. These gaps act as inlet and outlet headers for the cooling air. The inlet air header is bridged, between the holes in the concrete shield and the channels in the graphite, by tubes which serve as guides along which the uranium cartridges can slide. These bridging tubes are provided with adjustable holes to regulate the admission of cooling air to the channels. Similarly, on the outlet side, channels are provided to bridge the air header and allow the irradiated cartridges to be discharged into a heavily shielded magazine type coffin. Two hydraulic hoist platforms are located outside the shield at the charge and discharge faces, and these enable any channel to be reached for charging and discharging operations.

Cooling is carried out by drawing air through the core in a single-pass system and discharging it up a 200ft stack. An exhauster system was chosen in order to maintain a sub-atmospheric pressure around the core, and thus prevent any possible leakage of radio-active air or, more important, of airborne radio-active dust, into the pile building. The air is first drawn through an inlet filter and passes through a Venturi to the inlet header, where the quantity of air to each channel is regulated by means of the adjustable opening or valve in the bridging tube. This adjustment is desirable because the heat release is not uniform throughout the core. It is greater in the centre and falls off towards the edges and it is therefore unnecessary to draw the full amount of air through the outer channels. From the outlet header the air passes through another filter to the exhausters, of which there are five installed.

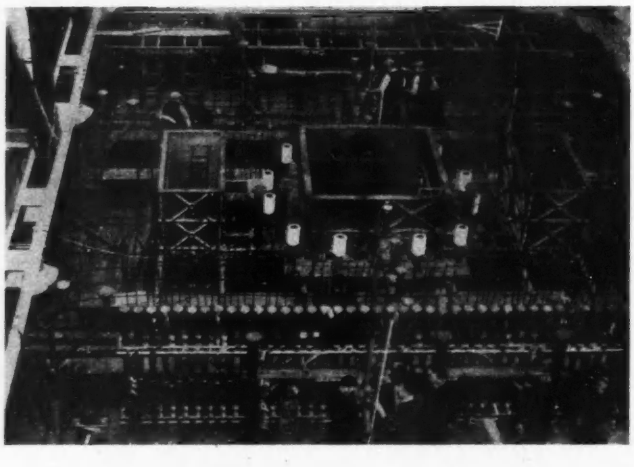


Fig. 4—General View During Construction of BEPO

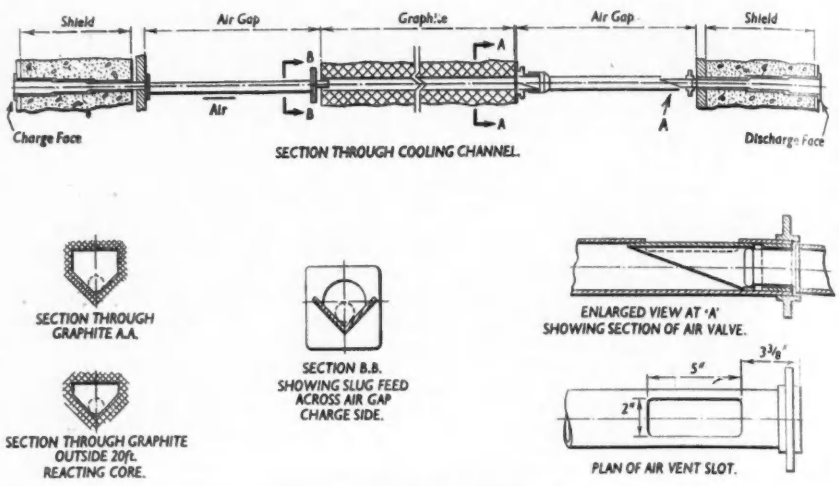


Fig. 5—Details of BEPO Channels

Normally, three are in operation, one is available on immediate standby, and the fifth is undergoing routine maintenance. Each exhauster is capable of handling 65,850 cubic feet per minute with a pressure difference of 2·6 lb per square inch. The motors are rated at 1400 h.p. and the rotational speed is 2960 r.p.m. Auxiliary exhausters are provided for operation of the pile at low power and for use during shut down. The outlet temperature of the air from the pile is of the order of 80 deg. to 90 deg. Cent. (176 deg. to 194 deg. Fah.), but it depends on the ambient temperature. The outlet duct is lined with aluminium sheet and the inlet duct is painted, to ensure that the air does not pick up dust from the concrete. After the pile had been in operation for a short time a water heater was installed in the hot air outlet duct; this has a nominal output of 2000kW and produces hot water at 72 deg. Cent. (161·6 deg. Fah.), which is used for heating buildings in the Research Establishment.

Control of the pile is effected by means of four control rods consisting of steel tubes 2in in diameter filled with boron carbide which is a neutron-absorbing material. These are arranged horizontally at right angles to the uranium channels and are moved in and out by electric motors. They can be operated at two different speeds by manual push-button control, but they can also be switched over to automatic control for holding the reactor at a fixed power level. The reactor is shut down by introducing ten similar rods in a vertical direction. There is provision for automatic shut down in any emergency.

One of the principal difficulties in the design of a nuclear reactor is to find suitable materials and methods for canning the uranium. Canning is necessary, first, because uranium is oxidised very readily in air, and, secondly, because there would be a release of highly active fission products into the air stream if no protective containers were provided on the uranium fuel elements. It is also necessary to provide some form of extended surface on the fuel elements to achieve the necessary transfer of heat to the air. The canning material must not be a heavy absorber of neutrons and it must be chosen with due regard to mechanical properties, thermal conductivity, and metallurgical compatibility. Increasing the extended surface makes the heat removal easier, but reduces the reactivity of the pile because, for any given material, the greater the weight of the can, the more neutrons it will absorb. Pure aluminium was chosen as canning material for the BEPO fuel elements and has proved satisfactory.

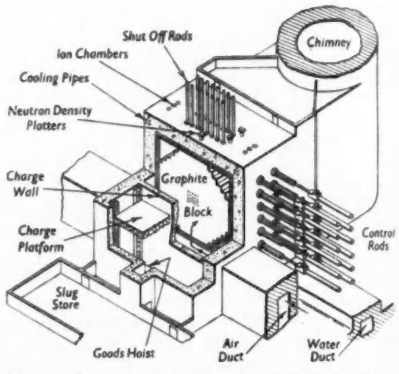


Fig. 6—Isometric Diagram of a Windscale Pile

It is impossible to guarantee that occasional failures of the fuel elements will never occur. Bursting of a can would lead to the release of highly active materials into the air stream. Means are therefore provided for locating any defects which may develop in the cans before deterioration has gone too far.

BEPO has operated without any breakdown; it has been a useful research tool and in a sense it has become a production pile, since one of its main uses now is for the manufacture of radio-isotopes. The experience which was gained in designing and building it was extremely valuable. At first it is worrying to feel that one is designing a complex and expensive plant where, if breakdown occurs, it is impossible to get access for repairs. Without doubt this feeling led to a standard of accuracy in construction of BEPO, which was not justified, and the techniques which were learned there enabled the designers to approach the design of the much larger

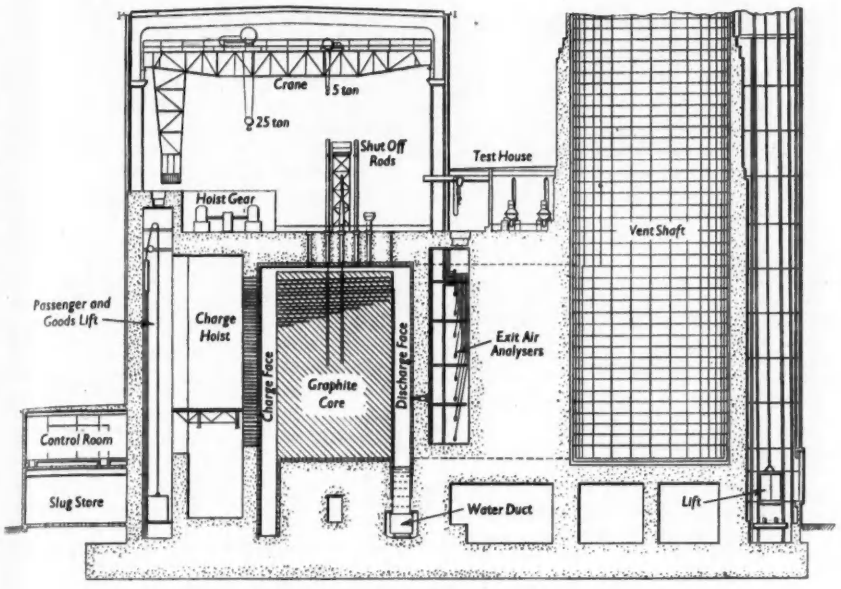


Fig. 7—Schematic Cross Section Diagram of a Windscale Pile

Windscale piles with some confidence.

The Windscale Piles.—Security considerations limit the information which can be published about atomic piles. A fairly full description has been given of BEPO because most details of its construction have been classified. The Windscale piles cannot be similarly fully described, but they can be understood by remembering that in principle they are similar to BEPO. They are very much larger in size and were built not for experimental purposes, but for production of plutonium on an industrial scale.

It was the original intention to build graphite-moderated water-cooled piles, since it was argued that a higher specific thermal rating could be obtained with water cooling. Water, however, absorbs neutrons more readily than graphite, so that any loss of coolant from the core of the reactor would lead to an increase of reactivity. The consequence of a run-away following a major coolant failure might be serious, leading to release of fission products and contamination of the surrounding countryside, and it would therefore be possible to build such a reactor only on a very remote site. The inconvenience of such a location was so great that it was finally decided to adopt air cooling.

An isometric diagram of a Windscale pile is shown in Fig. 6 and schematic diagrams of one of the Windscale piles are shown in Figs. 7, 8 and 9. It will be seen that, once again, the mass of graphite moderator lies within a biological shield. In this case, the main shielding is required to reduce the escape of neutrons and gamma-rays only to the point of biological safety and not, as in the case of BEPO, to a level which would make accurate experimental measurements possible around the pile. The shields are also pierced by fewer holes than in the case of BEPO, since only limited experimental facilities are provided. For this reason it was possible to use forced draught instead of induced draught for the cooling air, thus ensuring that the blowers cannot be contaminated by active material carried over from the pile. Both inlet and outlet filters are provided as at Harwell. The inlet filters are built into the walls of the blower houses and the outlet filters are located near the tops of the discharge stacks. Continuous monitoring of the uranium channels is carried out in order to detect any burst slugs.

Loading and unloading arrangements had to be designed for handling cartridges at a much higher rate than in BEPO. The charge platform is housed within the main biological shield, but with a subsidiary shield or charge wall separating the charging room from the face of the pile. On the discharge side a water duct is provided below the pile, and this passes through the main shield to connect the discharge space with an external storage pond. An under-water railway extends from the discharge space to the pond. Irradiated cartridges, which are discharged from the channels in the graphite core, fall into a hopper carried by a truck on the under-water railway. They can thus be transferred to the pond for cooling and decanning prior to processing in the chemical separation plant. The water duct also allows limited access to the interior of the pile shield for a man in a diving suit, who will be protected from radiation by the water above him.

As in the case of the Harwell pile control is effected by rods passing through the side walls into the reacting core, while emergency shut-off is by means of vertical rods which drop through the roof into the core.

The Windscale piles are of considerable size. They are built on a foundation of alluvial ballast which will take a maximum safe load of 2·5 tons per square foot. After considerable thought it was decided to make them monolithic structures, and so to avoid the problems of relative movement which would arise if chimney and pile were built on separate foundations. The biological shield walls, which in any case had to be reinforced to take care of the thermal stresses arising from the temperature of the core, were used to secure the rigidity of the monolith, and the foundation raft was regarded as a flange on the bottom of this box-like structure. Each raft had an area of 21,000 square feet and the total load on it amounted to 58,000 tons. The eccentricity of the loading had to be carefully watched not only in the completed structure, but also in the course of construction, and concrete work proceeded in a cycle of lifts which was designed to ensure this.

The construction of the top shield over the pile vault was an interesting problem, as it had to be built to a high degree of accuracy without the use of interior scaffolding and without the leakage inwards of any grout while the concrete was being poured. It was done by spanning the walls with Bailey bridge structures (Fig. 10), from which was suspended steel plate permanent shuttering which was welded to prevent leaks. The whole plate was given an initial upward curvature by the use of turnbuckles in the suspension rods. This camber was calculated to offset the deflection which would be caused by the weight of concrete in the roof which was 8ft 6in thick. Tubes were welded into the permanent shutter plate to form the holes for the shut-off rods and other equipment. These holes had to finish up accurately positioned and vertical to close limits. The final level was, in fact, accurate to within $\frac{1}{8}$in, and in no place did the roof drop below horizontal.

The chimney was originally designed as a tapered, reinforced concrete stack. At that time it was considered that no filter would be required on the outlet air from the pile, but when the chimney had been constructed to a height of about 70ft, research work showed that it was desirable to filter the outlet air. After careful consideration of alternatives it was decided that the best course was to put the filter at the top of the chimney. To make this change while still keeping the final completion date was not easy. The design was changed to a parallel chimney 44ft in diameter and 404ft high

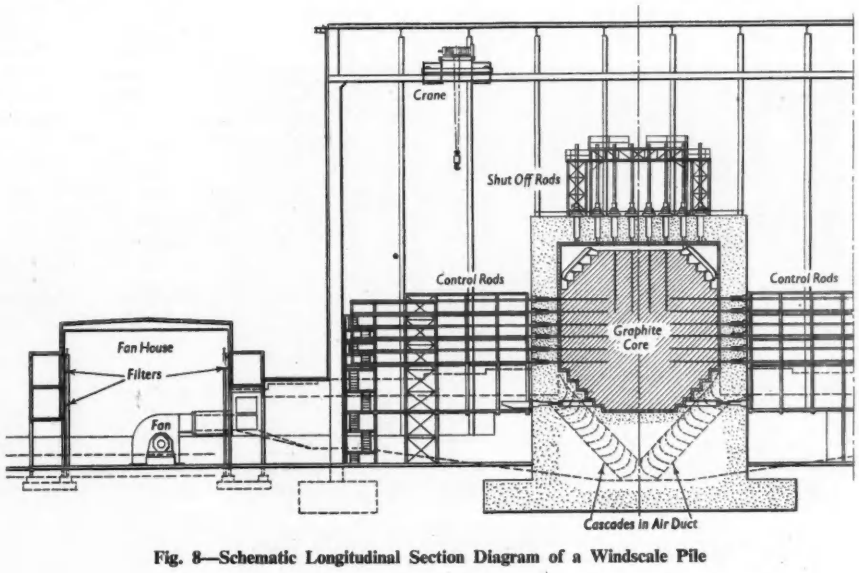


Fig. 8—Schematic Longitudinal Section Diagram of a Windscale Pile

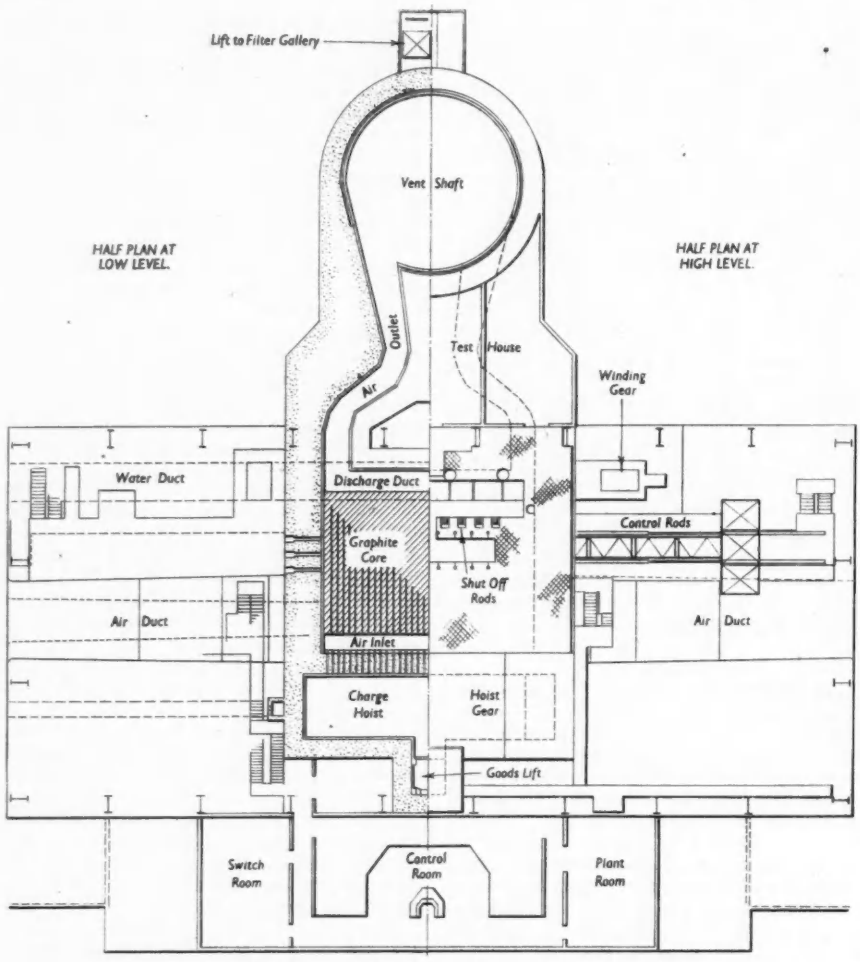


Fig. 9—Schematic Half-Plan Diagram of a Windscale Pile

overall. The filters were accommodated in a structural steel framework which rested on the top of the chimney barrel. The total weight of the structure, including the steelwork, was over 3000 tons and the problem of vertical transport of material for construction presented some difficulty. Internal and external scaffolds were built to accommodate eight construction hoists and the necessary false work. Within this filter structure the internal cross section of the chimney changed from round to square and back to round again. The filter units have to be removed by remote control after use as they are radio-active and they are taken to the bottom of the chimney, in their protective lead coffin, in a 7½-ton hoist which is attached to the stack by slip fastenings to allow for differential expansion.

In designing the graphite moderator it was necessary to allow for an air load of about 300 tons tending to blow the graphite towards the chimney; this load is carried by transverse joists across the discharge face and a vertical knife edge girder up its centre line. It was desired to keep the whole graphite structure in compression sideways. This was achieved by coil springs abutting against "top-hat" section beams let into the sides of the graphite, and against the thermal shield. Since the thermal shield was attached to the outer concrete shield, and since graphite, steel and concrete all have different coefficients of expansion, some ingenuity had to be shown in locating the fixing points. In spite of the massive thickness of concrete, the strength of the shield wall determined the sideways force which could be applied to the graphite. Stacking of the graphite core started while the structural work was still in progress. The vault was temporarily sealed off and vacuum cleaned, ventilation air was filtered and all men working in the vault changed into special clothing.

Cooling air is supplied to the pile by a number of double-entry, radial-flow, centrifugal blowers running normally at a speed of 990 r.p.m. Each is driven by an 11kV wound rotor induction motor giving 2400 to 3000 b.h.p. They are situated in two blower-houses, the walls of which contain inlet air filters, consisting of both wet and dry filters. The concrete floors of the blower houses are of dustproof concrete, and the concrete air ducts to the pile are lined with "Alclad" sheets to prevent erosion of the concrete.

In looking at the Windscale piles with such details as have been given of them, you will be struck by their essential simplicity. This is, indeed, the key to pile design. The problems as initially presented to the designers rarely looked simple, sometimes they looked almost frightening in their difficulty and more often they were frightening in their high content of the unknown. The main skill in pile design has been in reducing such problems to terms in which they could be interpreted into engineering structures so simple, so well understood, that even the unknown ceased to give cause for alarm.

(To be continued)

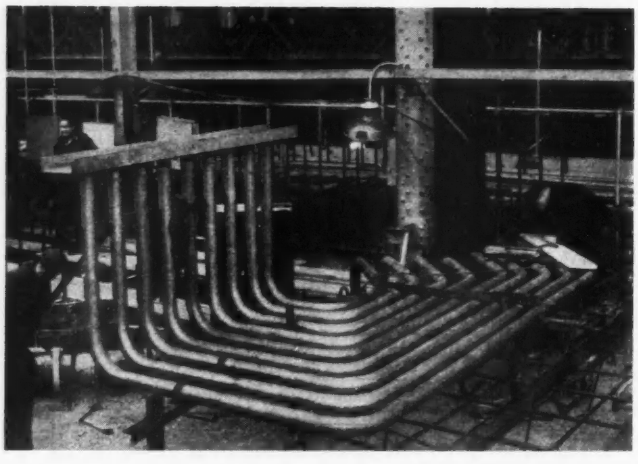


Fig. 10—Bailey Bridge Structure Supporting Permanent Shuttering for Top Shield

Rotating Centres

We are informed by A. A. Jones and Shipman, Ltd., of Leicester, that it has introduced a new range of "J. and S.-Lunzer" rotating centres for Morse taper sizes No. 1 to No. 6 and parallel shanks from ¾in to 2¼in. Each size is made in a series of spindle points, including female, tube, and reduced point models for copy turning.

The photograph we reproduce shows a section through a typical taper shank centre. In the centre the heavy radial and thrust loads are carried on three preloaded bearings of which the taper roller bearing carries the thrust and shares radial loads with the angular-contact ball bearing. The third bearing at the tail end of the spindle is, according to the size of the shank, either a replaceable, steel-backed, thin-wall, lead-bronze bearing or a needle-roller bearing, and, in the case of the largest models, two angular-contact ball bearings preloaded back-to-back.

The seal throws out coolant and grit that may penetrate by means of an internal thrower lip, and the gutter formed in the cap which has four drainage holes. A two-lip neoprene seal is fitted in the cap.

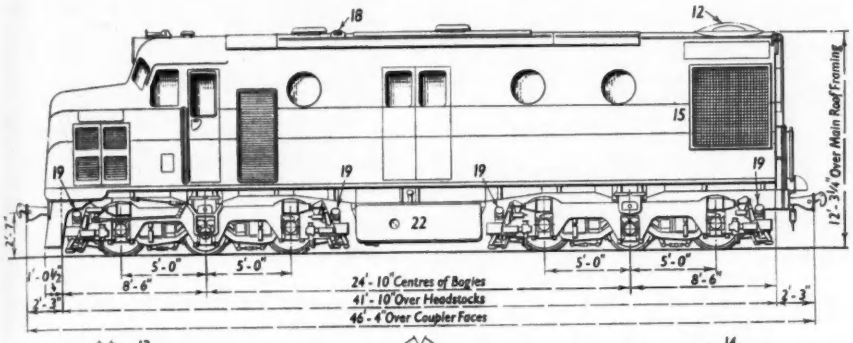
To prevent chatter and deflection at the neck of the taper shank when heavy loads or interrupted cuts are encountered, a steel ring is mounted between the shoulder of the rotating centre housing and the face of the tailstock ram. These steady rings are supplied oversize on thickness, for the user to face down to suit the gap between the housing and the ram.

Taper Shank Rotating Centre

Diesel-Electric Locomotives for Australia

Fourteen A1A—A1A diesel-electric locomotives are being built for the Commonwealth Railways of Australia by the Birmingham Railway Carriage and Wagon Company, Ltd. These locomotives have 955 b.h.p. Sulzer engines and Crompton Parkinson electrical equipment. With a maximum tractive effort of 26,800 lb they are designed to haul 270-ton trains up 1 in 60 gradients.

LAST week a demonstration run was given in this country of the first of fourteen general purpose diesel-electric locomotives being built for service on the Central Australia and Northern Australia lines of the Commonwealth Railways of Australia. The order for these locomotives was placed with the Birmingham Railway Carriage and Wagon Company, Ltd., of Smethwick, Staffs, as the main contractors, the engines and auxiliary equipment being supplied by Sulzer Bros. (London), Ltd., and the electric and control gear by Crompton Parkinson, Ltd. The locomotives have been constructed to the requirements of Mr. P. J. Hannaberry, the Commissioner for Commonwealth Railways.



1—Engine.
2—Generator.
3—Main control cubicle.
4—Auxiliary control cubicle.
5—Air compressor.
6—Traction motor blower.
7—Controller stand.
8—Air filter cabinet.
9—Air filter to cab.
10—Auxiliary water tank.
11—Auxiliary fuel tank.
12—Radiator fan and motor.
13—Hand brake.
14—Radiator.
15—Radiator louvre.
16—Water tank.
17—Water pump and motor.
18—Engine exhaust.
19—Sand box filler.
20—Batteries.
21—Air reservoirs.
22—Fuel tank—700 gallons.
23—Control air reservoir.
24—E.P. magnet valves.
25—Lifting jacks.
26—Re-railing ramps.

General Arrangement of Locomotive

The Central Australia line, which runs northward from Port Augusta, some 700 miles to Alice Springs, rises to an altitude of 1900ft, and it has a ruling gradient of 1 in 60, with uncompensated 460ft radius curves. The atmospheric conditions on this line are severe, as temperatures of over 100 deg. Fah. which prevail for eight or nine days on end reach a maximum of 118 deg. Fah. These temperatures and a humidity of 30 per cent, and hot sand-laden winds provide difficult locomotive working conditions. The Northern Australia line which runs south from Darwin to Birdum, a distance of 316 miles, has much less steep gradients. Speeds on these lines are restricted to 50 m.p.h.

It was specified that the locomotives should be capable of hauling 202-ton trains up a 1 in 60 uncompensated gradient, but as constructed they are actually capable of hauling 270 tons up this gradient. The light rails on the 3ft 6in gauge track made it necessary to restrict axle loading to 10·3 tons and this figure has been attained without the use of any light alloys in the structural members.

As part of the contract four spare 4ft 8½in bogies are being provided so that it will be possible to use two of the new locomotives on standard gauge sections of the Commonwealth Railways. When the new 4ft 8½in line from Stirling to Leigh Creek has been built and the line on from Stirling to Marree converted all the lines of the southern section of the system will be standard gauge. These lines will be able to take 12-ton axle loads and all the electrical equipment of the present locomotives is designed to take full advantage of this increased loading at starting.

The general arrangement of one of the new locomotives and its leading dimensions can be seen in the drawing we reproduce on this page. Other particulars are given in the table below.

In the new locomotives a completely welded superstructure of steel plate and pressed sections is riveted to a welded under frame. The end buffing load of 100 tons and the weight of the equipment is taken by the under frame without any help from the body framing, and the drag and buffing shocks are taken directly by the main longitudinals. These longitudinal members are of box section and are used as ducts to distribute ventilating air from the blowers to the traction motors. The main transoms are specially designed to accommodate the low position of the centre pivots. The outriggers are so arranged that there is a clear run below floor level for a main cable duct down one side and a similar space for air piping down the other side. These spaces are covered with removable aluminium floor plates which give free access to the cables and pipes. From the cab bulkhead forward the flooring is of steel plate which forms part of the strengthened anti-collision nose housing the brake reservoirs and batteries. Central buffing and draw gear is fitted.

Leading Particulars of Diesel-Electric Locomotives

Gauge	3ft 6in
Wheel arrangement	A1A—A1A
Driving wheel diameter	36in
Carrying wheel diameter	30in
Bogie wheel base	10ft
Maximum weight in working order	62½ tons
Adhesion weight	41 tons
Engine (one hour rating)	955 b.h.p. at 750 r.p.m.
Engine (continuous rating)	850 b.h.p. at 700 r.p.m.
Generator (continuous rating)	535kW at 700 r.p.m., 535V, 1000A
Traction motors, four (continuous rating)	165 h.p., 250A
Maximum tractive effort	26,800 lb
Tractive effort (at one hour rating)	20,000 lb at 11 m.p.h.
Tractive effort (continuous rating)	15,500 lb at 15 m.p.h.

Hatches, doors and a removable section of the roof give full access to the interior of the superstructure of the locomotive for maintenance and inspection purposes. The engine-room has six fixed circular and four fixed rectangular windows for lighting purposes, and its hatches and doors are fitted with seals to maintain pressurised conditions within. A 700-gallon main fuel tank slung below the under frame is supplemented by a 50-gallon service tank in the engine-room roof. Four traversing screw jacks and two re-railing ramps are included in the general equipment of each locomotive.

Both the bogie frame and the bolster are welded steel assemblies, the main frame members being of box form, except for the side members which are made of open box shape to accommodate the equalisers. Although the bogie is of swing bolster design the bolster itself is not sprung, the complete suspension being in the form of nests of helical springs set between the side equalisers and the frame. Very soft springing is used in order to provide easy riding over light tracks, and it is supplemented by shock absorbers which serve to damp out bouncing. The bogie swing links are carried on knife edges and the side swing is stabilised by horizontal pre-loaded rubber springs, any side motion being finally limited by rubber stops. Timken roller axleboxes are fitted and their manganese steel thrust faces bear against liners of the same material. The flat bogie centre pivots and side plates have wearing reinforcements of manganese steel.

In designing the bogies particular care was taken to ensure that all the vertical loads, and the traction and braking stresses, should be taken centrally and all in line on the main frame members. A bogie under frame interlock is provided on each side to prevent a bogie slewing

955 B.H.P. Diesel-Electric Locomotive

round in the event of a derailment, and to prevent the superstructure lifting off the bogie.

The disc wheels with integral tyres each have two brake blocks operated through clasp rigging. An Australian Westinghouse "A7-EL" brake system has been fitted and each bogie carries four 8in horizontal brake cylinders and the Australian pattern of slack adjuster. Air for the brakes is provided by a Westinghouse two-cylinder reciprocating compressor which also supplies the air for operating the sanding gear and the electro-pneumatic control gear. In two locomotives being allocated to Northern Australia the compressors will be arranged with one cylinder acting as a compressor and the other as an exhauster. Sulzer anti-wheel-slip brake gear is fitted to assist heavy starting under load adhesion conditions and it comes into effect automatically whenever the sanders are used for starting.

The full width driving cab is double-sheathed with outer panels of steel and inner panels of aluminium with "Isoflex" insulating material between. The double bulkhead between the cab and the engine-room is insulated with asbestos. The cab floor is arranged on two levels, the seats for the driver and his assistant being raised so that the driver can operate all the essential controls without moving or having his clear view of the track ahead obstructed. The controls include the power controller, reversing key, engine start and stop levers for two engines, a deadman pedal, combined brake controller for the locomotive and train, instrument panel, lighting switch panel, wheel-slip indicator, sanding valve, recording speedometer and a horn. Tinted "Perspex" sun vizors are fitted inside the front windows which have air-operated wipers outside.

The Sulzer "6LDA28" pressure charged, vertical, four stroke engine has six 280mm by 360mm cylinders. It is housed in a commodious engine-room which is pressurised to prevent the ingress of dust and dirt. Under Australian conditions this engine has a one hour rating of 955 b.h.p. at 750 r.p.m. and a continuous output of 850 b.h.p. at 700 r.p.m. Under normal European conditions the engine would have a one hour rating of 1035 b.h.p. at 750 r.p.m. Its guaranteed fuel consumption on continuous rating is 168 g per brake horsepower hour.

The construction of this engine follows the maker's normal practice and it can be seen complete with the generator on the common welded steel underbed in one of the accompanying illustrations. It has a welded mild steel crankcase integral with the underbed and its cast steel transverse members are welded in. The welded steel cylinder block bolted to the crankcase has cast iron wet liners. Main bearing saddles of "U"-shape have top caps let into the crankcase structure, and through a toothed wedge locking and adjusting device bearing adjustments as fine as 0·1mm can be made. On each cylinder head there is one inlet and one exhaust valve and individual fuel injection pumps with double helix plungers are fitted. Supported on the main generator frame at the back of the engine is the exhaust-gas pressure charger.

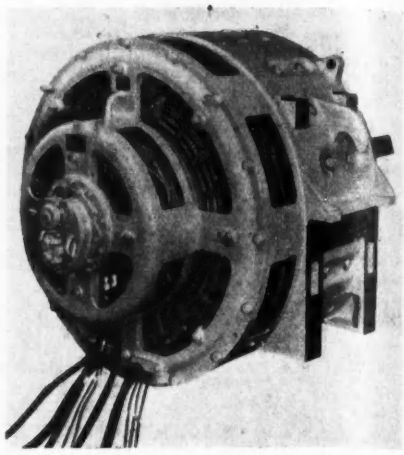
The engine circulating water and lubricating oil is cooled in two side radiators built up of Serck elements. Air is drawn through the radiator bank and expelled upwards through the roof by an electrically driven fan. The motor of this fan is connected electrically to the motor of the traction motor blower and operated through contactors so arranged that the blower and fan run at reduced speeds until the main controller notch No. 5 is reached. The centrifugal pump of the cooling water system is driven by a separate motor, which starts up automatically with the main engine but continues to run until switched off after the engine has stopped.

The automatic system of load regulation ensures that the engine operates always under the most favourable conditions and lowest possible rotational speed according to the load required. The control apparatus is matched to the engine regulator in such a manner that the peak tractive effort at one end of the output curve, and a relatively high track speed at the other end, can each be obtained on a low controller notch. Higher notches are used for hauling heavy loads at high speeds or to give high rates of acceleration. There are eighteen notches in the controller and with each notch the engine torque and speed are increased. In the first four notches, which are used for starting, the tractive effort is also increased successively, reaching a maximum at notch 5.

With each notch corresponding to a fixed engine torque and speed combination, the engine governor so regulates the generator and traction motor field strengths that the engine cannot be overloaded, even should one or more cylinders not be firing. The regulator ensures that full power corresponding to each notch is available over practically the whole speed range on all notches. The amount of fuel which can be injected is automatically restricted by a device controlled by the outlet air pressure of the pressure-charging group for all load settings, so that protection against engine overload due to pressure-charger faults is also provided.

Full engine and power protective arrangements are included, so that power is cut off from the traction motors and the engine is shut down if there is loss of lubricating oil pressure, excessive rise in water temperature or loss of water pressure. Power is cut off from the traction motors and engine speed reduced to idling automatically if there is over-current on any one traction motor, an earth fault on any traction motor or on the main generator, a traction motor blower failure, or if there is a loss of control air pressure. The control gear was designed and manufactured by Allen West and Co., Ltd., to the requirements of Crompton Parkinson, Ltd.

The main generator is a Crompton Parkinson ten-pole machine with a continuous rating, to B.S.S. 173, of 535kW at 700 r.p.m., 535V, 1000A. An eight-pole auxiliary generator is



Main Generator with Recessed Auxiliary Generator

continuously rated at 63kW at 500 to 750 r.p.m., and 110V, 575A. As illustrated above, the auxiliary generator is recessed into the main machine, an arrangement which has been adopted to shorten the length of the power plant, but which does not entail the loss of accessibility to either machine. The armatures of the main and auxiliary generators are combined on a common rotor of cast steel and the coupling for the flange of the oil engine crankshaft is an integral part of the casting. Tandem brushes are fitted and their holders are carried on a revolving rocker with a rack and pinion gear through which the whole assembly can be rotated to give access to the brush holders. The main and auxiliary generator commutators are built on separate steel hubs.

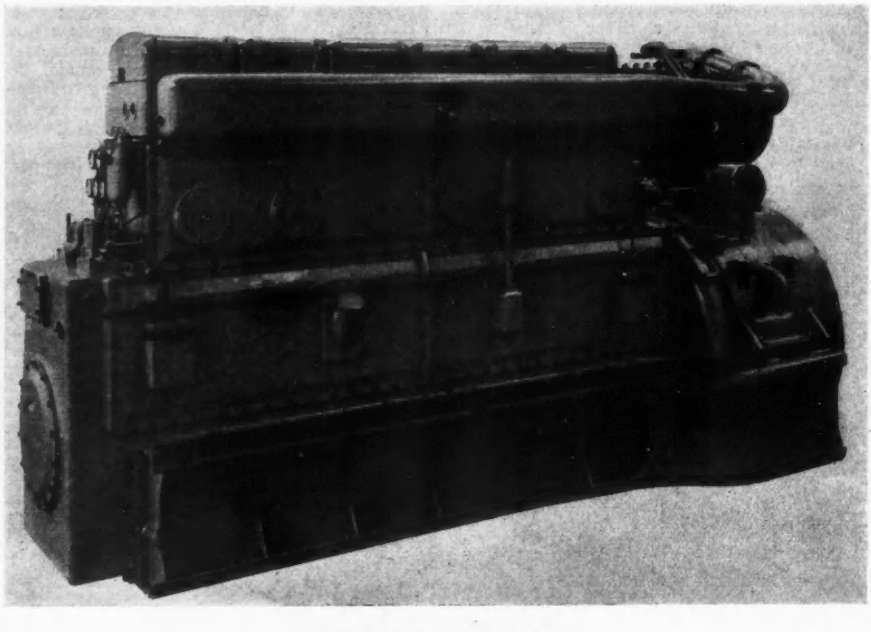
The complete main/auxiliary generator assembly is a single bearing machine with a parallel roller bearing at the outer end. This bearing is carried in a removable cartridge so that the end shield, and therefore the auxiliary generator magnet frame, does not have to be removed in the event of a bearing replacement being made. A hand barring gear on the inner end of the main rotor provides a simple means of turning over the whole engine-generator assembly. Also mounted on the main generator frame is the engine exhaust gas pressure charger and the generator field regulator driven from the engine regulator. The whole set is ventilated by pressurised filtered air.

Each of the four traction motors has a one hour rating of 197 h.p., 300A, 550V, and a continuous rating of 165 h.p., 250A, 550V. The motors are bar-suspended, there being a pivot between the motor frame and the bar, which has helical springs fitted above and below. A motor blower set in the engine-room is used for the force ventilation of the traction motors. In this set a single electric motor has a Keith Blackman blower at each end, and each blower serves two traction motors.

The four traction motors are in permanent parallel with field weakening introduced in three stages by means of electromagnetic contactors operated automatically when generator excitation reaches its maximum.

The motors of the circulating water pump and the compressor are supplied by a forty-eight-cell, 243 amp-hour lead acid battery, whilst the motors of all the other auxiliaries start automatically with the engine.

When necessary two locomotives can be operated back-to-back in multiple, and in this case each diesel engine is started and stopped separately from the leading driving cab.



Engine and Generator Assembly

Four-Storey Garage in Dusseldorf

AMONG the interesting buildings which have recently been constructed in Germany is a four-storied garage in Düsseldorf, which has been designed by the Düsseldorf architect, Dipl.-Ing. Schneider-Esleben, and built by the Gutehoffnungshütte Aktiengesellschaft of Sterkrade. The garage, which is seen to the right of our upper illustration has four stories which together can accommodate some 500 cars. With a prearranged parking schedule it is possible to pack the incoming cars somewhat more closely and space can then be found for over 600 cars.

The main structure consists of fifteen sets of three vertical reinforced concrete columns which carry the floor supports, and are framed together. At the top, the roof beams are cantilevered outwards, to take the vertical tie rod supports for the inclined ramps. The floors and the roof are longitudinally framed, and the longitudinal beams carry the glazing bars.

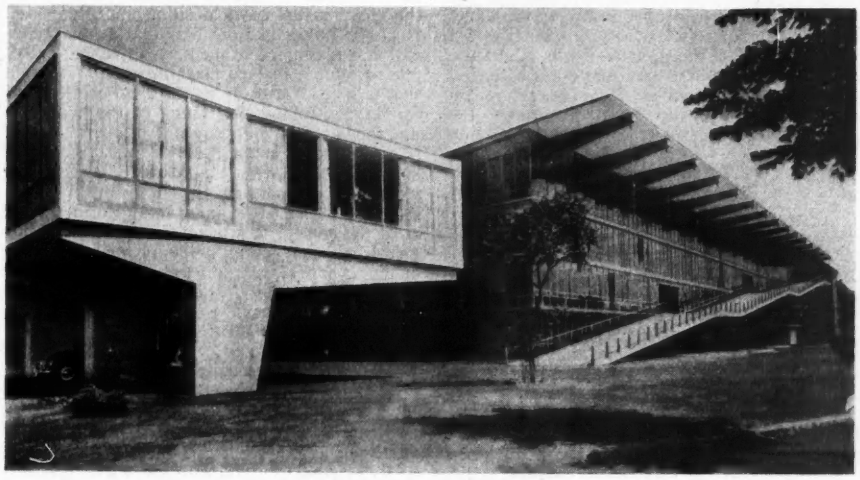
The cars enter the garage by means of the inclined ramp, and on the other side of the building is a similar ramp for exit. The ramps are hung on 30mm diameter steel rods, from the cantilevers of the transverse frames. They have an inclination of 14·5 per cent, and at each storey there is a flat platform, so that a car may easily enter the doors. The ramps are provided with heating elements which protect the surface from the danger of snow or ice.

The cars are parked on each floor in two lines each side of a central fairway, 7m in width.

The glazing consists of 6mm thick glass panels which are let into the angle or tee-iron frames which run all round the structure. In all, some 4000 square metres of glass were used. The doors for entry and exits are roller doors moved by hand.

The interior of the garage is warmed by radiant heat from the ceilings. The heating pipework was laid in the floor on top of the tension rods of the reinforcement, so that a portion of the warmth also reaches the space above the floor. A boiler in the cellar provides the heat. In the heating system for the ramps glycerine is introduced into the circulating water to avoid difficulty in frosty weather. The boiler installation is at present coke fired, but it will be later modified for oil firing, and it is hoped to use most of the spent oil from large cars in the burners. For ventilation two exhaust fans are provided. They are housed above the staircase wells on the roof of the building. Each fan has a designed duty of 43,000 cubic metres of air per hour. The exhaust air is drawn into ducts constructed in the space between the two centre supporting girders. Fresh air enters through the doors and windows. The ventilation plant is designed for three complete changes of air each hour. Fire mains extend all round the walls of the two middle stories, and there are a number of drenching pipes with a diameter of 15cm, which can provide a curtain of water over the windows to prevent the spreading of fire from one storey to another. All the rainwater from the roof is taken away inside the building by pipes down the main central columns. After passing through a petrol separating plant, which was specially designed to deal with the waste water from the car washing and spraying installations, waste water goes into the town's sewage system. The garage is illuminated throughout by fluorescent lighting, only the staircases being lit by ordinary light bulbs.

The car washing plant is arranged in the ground floor of the building. There are two lines of car washing equipment, each of which consists of a pit for washing the underside of



Hotel and Garage in Dusseldorf

The Hotel Alongside the Garage Surmounts the Petrol Station

The Structural Arrangement of the Garage is Here Clearly Revealed

the cars, and two stands for washing the outsides The installation has a sloping floor with a fall of 1·5 per cent, so that the cars can be easily moved on from one washing process to the other. The ground floor also contains a set of six lifting turntables. Other equipment includes two enclosed spraying booths.

As will be seen from our illustrations, a hotel has been built alongside the garage. It has forty rooms and a restaurant. The hotel building stands on a series of T-shaped reinforced concrete frames, which provide room below the hotel for the main entry and exits to the garage, and a petrol station. The caretaker's lodge and the control room and the pay office are arranged below the hotel building. The hotel rooms are heated by radiators which are connected to the main garage boiler installation.

Pneumatic Press Brake Guard

PARTICULARS have been received from Rubery Owen and Co., Ltd., Darlaston, of a pneumatically operated press brake guard which can be adapted to fit any design of mechanical press. On a machine fitted with this equipment, upon depression of the clutch pedal, the guard apron descends to a set position above the work-piece and prevents access to the tool space before the clutch is engaged for the working stroke. The guard is locked in this down position by air pressure until the tools contact the work, when it automatically starts to rise so that the work-piece is formed without interference from the guard. The guard apron is supported and balanced on an arm, and initially it descends by gravity. In the event of an obstruction the guard cannot descend a sufficient distance for its arm to operate a relay valve which controls the air supply for the subsequent guard locking and clutch engaging operations.

The operating cycle of the guard pneumatic system can be seen in the diagram we reproduce. When the guard apron is in the up position, as shown, the upper chamber of the double acting cylinder *A* is opened to a supply of compressed air through automatic guard valve *B*, and air is also admitted to a trip valve *C* through an automatic clutch valve *D*. This clutch valve also serves to control the air feed to a single acting clutch cylinder *E*. As at this point there is no supply of air to the clutch cylinder the clutch cannot be engaged to drive the press.

A hand valve *F* can be positioned so that the guard can be fixed in the up or down position for tool setting, piercing operations, &c. ; or it can be moved to the automatic operating position in which the pneumatic system is operative.

When, with the control handle in the automatic position, the clutch pedal is depressed by the operator of the press the valve *C* is tripped and air is admitted to the guard valve *B*. The changeover mechanism of this valve is actuated and through it a supply of compressed air is fed onto a relay valve *G*, where it is held in reserve for subsequent use. At the same time the air already contained in the double-acting cylinder *A* is automatically exhausted, and the guard apron descends under gravity. If there is no obstruction and the guard descends to its lowest operative position its counterbalance arm actuates the relay valve *G*. The reserve pressure of air in this valve is thereupon transmitted to the lower end of the air cylinder *A* and locks the guard in the down position under pressure. It should be pointed out here that a rotary control unit is coupled to the press drive and makes one revolution in each machine cycle. Through this unit the valves *H* and *J* are operated, the former controlling the timing of the guard lift and the latter the press cut-out.

At this stage in the cycle of operations air is supplied to the clutch auto-valve *D* actuating its changeover mechanism to transmit a charge of air to the clutch cylinder and also to a valve *H* of the control unit in readiness for lifting the guard. In its action of supplying air to the clutch cylinder the auto-valve *D* exhausts air from the trip valve *C* which resets. This ensures that once the guard has returned to the up position it cannot be operated again until the next machine cycle.

With the guard locked down the ram of the press brake descends, and, at a point determined by the setting of the control, the valve *H* is opened. By the air which then flows from this valve the automatic guard valve *B* is returned to its original position and the guard apron is raised by the admission of air to the upper end of the cylinder *A*. The press continues its working stroke and at the top dead centre of the subsequent return stroke the valve *J* of the control unit is actuated. The air passing through this valve operates the changeover mechanism of the clutch valve, which reverts to its original position and exhausts the air from the clutch cylinder *E*. The air supply is automatically restored to the trip valve *C* ready for the next operating cycle.

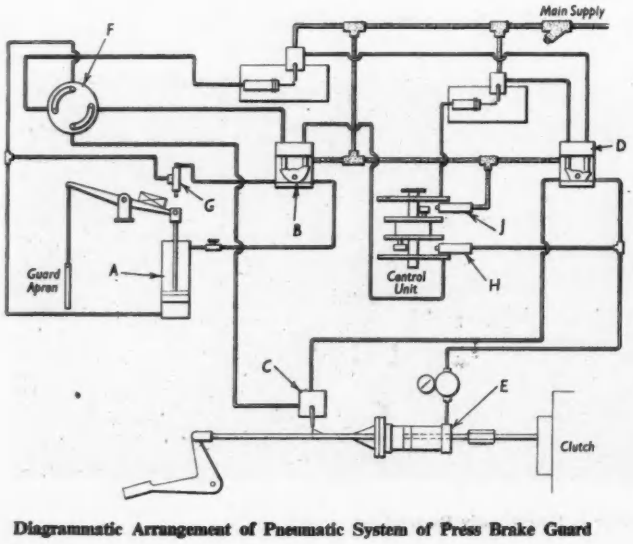
Symposium on Training in Cargo Handling

ON Monday, January 25th, the International Cargo Handling Co-ordination Association held a Symposium on Training in Cargo Handling in Rotterdam, and the delegates were welcomed by Dr. J. Ph. Backx, the president of the Netherlands National Committee of the Association. In the morning two papers were read. The afternoon session opened with an address, entitled "The Rotterdam Dockers' School," given by Mr. A. Peters, Jr., the Director of the Foundation "Dockers' Training School," and was followed by a visit to the school. Then another paper was read and the Symposium was concluded by some remarks by Mr. D. R. Woodley upon "Problems Involved in the Institution of a Course in Cargo Handling."

The first paper, in the morning, entitled "The Need for Education in the Dock Industry from the Employers' Point of View," was presented by Mr. D. Rylandes Smith. The effect of modern education was generally considered and the lack of training in the dock industry commented upon, while due praise was given to the example set by the port employers of Rotterdam in this matter. Pride in modern plant, it was stated, was not enough, for it was necessary to teach the dock worker, not only the principles of his job, but also why he was doing it and how to use the machines, and, in addition, accept mechanisation at its correct value. The second paper was read by Mr. R. Laan, who put forward the students' views on training, and the third paper, with the title "Education and Training in Cargo Operations," was prepared by Commander C. L. Sauerbier, U.S.N.R., and read by Mr. D. R. Woodley. After stating that most of the improvement of cargo operations was a matter for the longshoremen in the hold, haphazard training methods were condemned as being detrimental to progress and resulting in inefficiency. An organised training programme was maintained to be essential in order to produce enthusiasm for the job, improvement in performance, greater safety, higher personal standards and greater pride in the job. The education of ship's officers in cargo operation was examined and discussed in some detail, and an appendix to the paper set out the syllabus of the course in cargo operations as taught at the United States Merchant Marine Academy, King's Point, New York. As already mentioned, the Symposium was concluded by Mr. D. R. Woodley, who based his remarks on some twenty-four headings which referred to the various points to be solved before deciding upon going forward with plans for instituting a course in cargo handling.

Diesel Tractor

THE diesel-engined tractor which is illustrated below has recently been put into production at the Kilmarnock works of Massey-Harris-Ferguson, Ltd. It has been designated as the "Massey-Harris 745," and is in most respects a development of the firm's "744D" diesel tractor. The engine fitted in the new tractor is a Perkins "L.4" four-cylinder diesel with replaceable wet cylinder liners. The bore is 4¼in and the stroke 4¼in, the compression ratio being 18·3 : 1. "Ki-gas" starting equipment is fitted to facilitate starting in cold weather, and the engine is rated to develop 44·6 b.h.p. at 1500 r.p.m. The engine is connected by a flexible coupling to the transmission, and the sump and the clutch can be removed without lifting the engine or splitting the tractor. The power is transmitted through Borg and Beck spring clutch to straight spur gears, and speed reduction



Diagrammatic Arrangement of Pneumatic System of Press Brake Guard

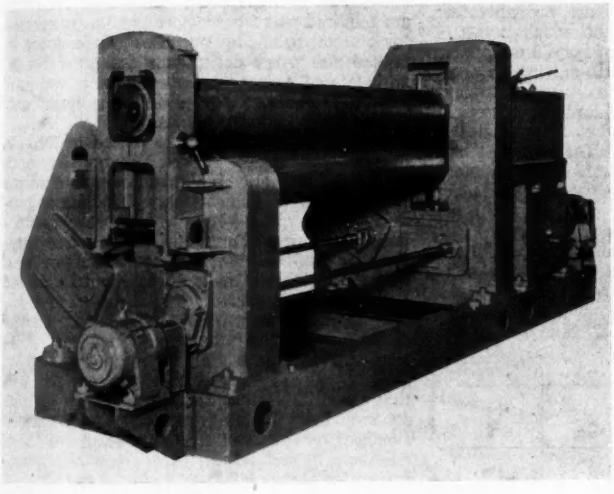
Diesel-Engined Tractor Pulling a Three-Furrow Mounted Plough

is obtained in three stages. The transmission provides for five forward speeds between 2·75 and 15·33 m.p.h., and a reverse speed of 3·62 m.p.h. when the engine is running at 1500 r.p.m.

The new tractor has been designed for a choice of rear-wheel equipment, and with wheels taking 12×38 pneumatic tyres the rear axle is adjustable from 54in to 84in track in 2in steps. There are also three variations of the front axle, the "high arch" design being adjustable from 54in to 74in track in 4in steps. The tractor's hydraulic equipment consists of a lift unit incorporating the oil reservoir selector valve, ram and lift shaft; a gear pump which, together with its drive coupling and mounting, is located on the front of the engine crankshaft and is coupled to the lift by two pipes; and a three-point linkage designed for use with all British Standards Category 2 implements. The hydraulic pump is permanently coupled to the front of the engine and thus operates whenever the engine is running. This arrangement has been followed so that the lift can be used both when the clutch is engaged and disengaged. Provision is made in the new tractor for a power take-off shaft and a belt pulley to be fitted as extra equipment.

Plate Bending Machine

We have received some details of a three-roll initial-pinch, plate bending machine, for mild steel plate up to 8ft long and ¾in thick, which has been made by the Bronx Engineering Company, Ltd., Lye, near Stourbridge. It is stated that this machine will bend plate to a circle with the minimum amount of flat on the long edges in one rolling pass only. The photograph we reproduce herewith shows the machine with its swing-down housing in the working position.



Initial-Pinch Bending Machine for 8ft Plates

The machine is built on a rigid fabricated steel base-plate to which the roll housings and the drive are bolted. All three of the machined, forged steel rolls are 13in in diameter. During plate forming operations the top and bottom rolls are driven whilst the side bending roll is idle. Housings of heavy welded steel plate enclose the worm gearing used for adjusting the setting of the bottom centre roll and the side roll. At the end of the machine opposite the drive the housing is provided with a swing-down bearing for the top roll to enable complete cylinders to be removed.

The rolls are driven by a 25 h.p., 945 r.p.m. slip-ring motor through totally enclosed double-helical gearing. Vertical adjustments of the centre bottom roll for gripping the work are effected by a 3 h.p. motor drive to adjustment screws through worm gearing. A separate 12 h.p. motor is used for side roll adjustment. Both the bottom roll and the side rolls can be tilted for forming conical work, by operating multi-jaw clutches in the adjustment driving shafts. The top roll cannot be adjusted and it has a long counterbalancing extension at the drive end to support it when the end bearing is swung down for removing work after rolling. For this purpose a hand-wheel operated support can be lowered to engage the ball at the end of the roll extension.

De-Rusting Fluid

Recently a demonstration was arranged by the Plus-Gas Company, Ltd., 1–11, Hay Hill, London, W.1, to show some of the applications of the fluid the firm makes for breaking down the bond between heavily rusted or corroded components, when dismantling machinery. The non-acid de-rusting fluid made by the firm is known as Plus-Gas Formula "A" and, when applied by a spray or pressure oilcan, it penetrates corroded parts to disintegrate the seal of rust. After parts have been freed the fluid can be wiped off and lubricant applied in the normal way, as it is claimed that no deleterious substance is left behind.

The demonstration was held in the scrap yard of Chamberlain Industries, Ltd., at Leyton, and visitors were invited to select any pieces of discarded equipment for trials with the fluid. The plant selected included an old conveyor chain, some of the links of which were so heavily corroded that they could not be moved by hammering; a cast iron muffle door, immovably bound to its steel hinge pin; a pulley rusted on its shaft and covered with hardened grease; and a large nut rusted on its bolt. Each of the components chosen was saturated with the fluid. In a matter of minutes the rust was loosened and washed out to free the parts completely, which could then be moved by hand where spanners or levers had previously proved ineffective. The fluid can also be used for removing surface rust and corrosion from ferrous metals, chromium, brass, copper, &c.

A complementary resin-based protective fluid, known as Formula "B," is also made by the firm. When applied to metals, it is stated, this fluid dries and produces a tough protective, flexible, transparent film, which resists corrosion. It is applied by brushing, dipping or spraying and need not be removed on assembly of components, as the coating is so thin that it does not offer appreciable resistance during fitting. As the coating material is not detrimental to lubricating oils, the firm states, it can be left on parts working in gear-cases, oil baths, &c.

Arc Welded Motor-Cycle Frames

To overcome some recent additional problems in the manufacture of motor-cycle frames, the London Application Centre of Philips Electrical Ltd., working in conjunction with Ariel Motors, Ltd., has put into operation a technique involving the use of electric arc welding as the main production tool.

The production of motor-cycle frames has always involved considerable design difficulties. Frames usually consist of preshaped drawn steel tubing held together with malleable cast lugs and stampings, and they require a complicated production procedure, involving accurate jigging, machining, brazing, &c. With this construction much depended on the frame builder, particularly in the jointing, where the large quantity of heat required often caused frame distortion. Designers therefore tend to provide as simple a structure as possible. The recent trends towards rear wheel suspension systems have, however, made quantity production more difficult. To strengthen the motor-cycle frame a duplex system had to be adopted which, due to its closed construction, is more prone to distortions than the common single tube design.

Motor-Cycle Frame on a Manipulator Used for Finish Welding. After Welding the Completed Frame is Checked Under a Setting Fixture for Alignment

With the new method and using a specially designed electrode the use of lugs has been largely dispensed with. Tubes are mitred and then arc welded directly to each other. All remaining secondary lugs are arc welded with the same electrode, only two malleable castings at major joint positions in the frame being employed. Fabrication procedure has been broken down to subsections wherever possible.

The considerable reduction of intricately shaped castings, has dispensed with a large amount of machining, and it is claimed that arc welding has considerably reduced frame distortion and has made possible the use of semi-skilled personnel on the assembly lines.

It is stated that the new method, as well as bringing about considerable savings in labour costs and factory space, has also resulted in an improved product. Extensive tests, far exceeding in severity conditions normally encountered, have been successfully carried out on the new frame.

Calculator for Gear Design

We have received a calculator based on the formulæ and charts contained in British Standards Specification No. 436: 1940 ("Spurs and Helicals") which has been introduced by Fearns and Mear, 22, Stanley Road, Lindley, for the determination of gear sizes. It is claimed to give the same results as the British Standard Specification, but to be very much simpler to use and to give in a few seconds results that would take an hour or longer to obtain by former methods. The calculator is similar to a circular slide rule in principle, and may be used to determine the allowable horsepower ratings for spur or helical gears on a wear or on a strength basis. Alternatively, for a given horsepower, it may be used to find the pitch, face width or material required.

To derive the allowable horsepower rating for a pair of gears it is first necessary to determine the zone or strength factor from the reverse side of the computer, which necessitates one setting of a cursor. The scales on the front of the computer are then set according to the value thus found and other information available, such as number of teeth, pitch, revolutions per minute, &c., and the allowable horsepower per inch of face for the gears may be read off directly. The computer has a range sufficient to cover pitches from 30 D.P. to 1 D.P. (or 0·1in C.P. to 3·14in C.P.); speeds 0·01 r.p.m. to 25,000 r.p.m.; number of teeth, 10 to 400, and horsepower from 0·001 to 75,000 h.p. in any material.

National Metal Exposition, U.S.A.

(By Our American Correspondent)

SOME 450 companies engaged in either the production, treatment or fabrication of metals gave displays and demonstrations of their products or services at the exhibition held last year at the Cleveland Public Auditorium. Over the years, the Metal Show has continued to become ever broader in its coverage of the metals and metal-working field, and gone are the days when it was concerned mainly with the heat treatment of steels. This year there was a strong accent on the fabrication and application of some of the more recently developed engineering materials, such as titanium, zirconium, beryllium and tantalum. Furthermore, there was a noticeable trend toward the display of more machine tools at this exhibition, and a considerable number of European imports were shown.

A wide range of titanium and titanium alloy components was exhibited at the stand of Rem-Cru Titanium, Incorporated, of Midland, Pennsylvania. The company is probably the largest producer of titanium in the United States at present and is in a position to supply bar, sheet, strip, plate, wire, tubing, simple forgings, billets and arc-melted ingots in both commercially pure and alloyed titanium. Other forms, such as rolled and extruded shapes and foil, will be made available at a later stage. The firm produces four basic materials: (1) "RC-70"—commercially pure titanium with a 70,000 lb per square inch minimum yield strength. This is the most widely used composition of titanium. (2) "RC-55"—commercially pure titanium with a 55,000 lb per square inch minimum yield strength. This is a lower strength, higher ductility material. (3) "RC-130-A"—titanium-base alloy with a 110,000 lb per square inch minimum yield strength. This alloy was developed to fill the need for a formable, structural sheet material with improved strength-weight properties in the intermediate temperature range. (4) "RC-130-B"—titanium-base alloy with a 130,000 lb per square inch minimum yield strength. This alloy was developed specifically for forgings and bar stock. The room temperature properties of these four materials are summarised in the following table.

Room Temperature Properties of Titanium Materials

	"RC-55" sheet	"RC-55" rolled bar	"RC-70" sheet	"RC-70" rolled bar	"RC-130-A" sheet	"RC-130-B" rolled bar
Ultimate tensile strength:						
Typical (1000 lb per square inch)	75	75	90	90	130	150
Nominal minimum (1000 lb per square inch)	65	65	80	80	120	140
Compressive yield strength (0·2 per cent offset) (1000 lb per square inch)	63	—	78	82	—	140
Tensile yield strength (0·2 per cent offset):						
Typical, long (1000 lb per square inch)	65	65	80	80	115	140
Typical, trans. (1000 lb per square inch)	65	—	80	—	120	140
Nominal minimum (1000 lb per square inch)	55	55	70	70	110	130
Tensile elongation (2in gauge):						
Typical (per cent)	25	25	20	20	15	18
Nominal minimum (per cent)	20	20	15	15	10	10
Reduction in area:						
Typical (per cent)	—	50	—	40	—	40
Proportional limit:						
Typical (1000 lb per square inch)	50	—	65	70	95	105
Bend ductility:						
Typical bend radius (up to 0·1in thick)	1·5T	—	2·0T	—	2·0T	—
Nominal maximum	2·0T	—	3·0T	—	3·0T	—

It is of interest to note that several of the American producers and fabricators of copper and brass strip are now "diversifying" their manufacturing programmes by including aluminium and aluminium alloy strip. As an example of this trend, the Scovill Manufacturing Company, of Waterbury, Connecticut, displayed at its stand samples of its so-called "Truspec" aluminium strip which it has recently begun to produce in a new cold rolling mill. By maintaining exceptionally close control of the inherent physical and mechanical properties of the metal, the firm has demonstrated that it has been found possible to minimise the undesirable "orange-peel" and "earing" effects in deep drawing work.

According to accepted theory, the formation of "ears" in drawing or forming operations is the result of inherent directional properties or preferred orientations of the grains in which the plastic-working of the coiled strip flows more readily in certain directions. Two such formations are present in aluminium alloys—one, the 0 and 90 deg. "ears" resulting from a predominance of the annealing texture; and the other, 45 deg. "ears," resulting from a predominance of the rolling texture in the annealed temper strip. When the two balance each other, no detrimental height of ears is found, and "non-earing stock" results. "Non-earing stock" does not mean that no "ears" are formed in deep drawing, but indicates that the degree of "earing" is such as not to prove detrimental to a drawn article processed in a normal manner. Usually, 3–4 per cent "earing" is considered satisfactory, and the firm considers strip causing only 1 per cent "earing" ideal.

An important new age-hardenable beryllium copper alloy was introduced at the "Metal Show" by the Beryllium Corporation, of Reading, Pennsylvania. Having a beryllium content of only 1 per cent, the alloy, which has been termed "Beryldur," may be described as filling the gap of physical property ranges existing between the two basic groups of beryllium copper alloys—the high strength and the high conductivity groups. There are probably few materials available at present which combine the many useful properties of beryllium copper, and they are often essential in solving an engineering design problem. In America to-day, "Berylco 25" is the standard high-strength beryllium copper alloy. It has a nominal 1·9 per cent beryllium content. The strongest and hardest of all copper alloys, it has been more and more used for parts that call for good electrical conductivity (25 per cent I.A.C.S.), as well as strength and hardness. "Berylco 10" is the standard high-conductivity beryllium copper alloy. In the heat-treated condition it has an electrical conductivity of 48 to 55 per cent I.A.C.S. and a tensile strength of 100,000 lb to 135,000 lb per square inch. It is used where thermal and electrical conductivity are more important than high strength and hardness. In recent years, with the increasing knowledge and use of beryllium copper, the company received many requests for an alloy with properties somewhere between the high-strength "Berylco 25" and the high-conductivity "Berylco 10." The new "Beryldur" alloy meets this need; it has a tensile strength of about 135,000 lb per square inch and an electrical conductivity of 18 to 26 per cent I.A.C.S.

The alloy is now available in two conditions: (1) heat-treatable strip, and (2) mill-hardened strip. It can be easily worked in the first condition, which should therefore be used where severe forming is necessary. A simple low-temperature heat treatment gives the material the maximum desired characteristics. When only mild forming is necessary, the mill-hardened condition of "Beryldur" has an advantage in lower handling and fabricating costs. The material, as supplied, has the following physical properties, having been heat-treated at the mill:—

Tensile strength, lb per square inch	125–140,000
Yield strength, lb per square inch, 0·2 per cent offset	105–125,000
Elongation in 2in, per cent	12–20
Rockwell hardness:	
"C" scale	22–30
"30N" scale	44–50
Electrical conductivity, per cent I.A.C.S.	22–26

An interesting metal of very high density was introduced as the exhibit of P. R. Mallory and Co., of Indianapolis, Indiana. Known as "Mallory 1000" metal, the material was developed in answer to certain military and industrial problems involving applications which require a machineable metal of high density. A homogeneous alloy composed of tungsten, nickel and copper, it has a density of 0·606 lb per cubic inch and is fabricated by powder metallurgy techniques which permit the placement of a large mass within a small or confined area. Compared with metals and alloys having densities similar to its own, such as platinum, gold, osmium and their alloys, "Mallory 1000" is inexpensive. Softer and less expensive metals like lead, mercury and tungsten, are unsuitable substitutes because of certain undesirable characteristics including lack of strength, fluidity and poor machineability. The material is at present used in three broad fields of application: as a rotating inertia member where precision-machined, homogeneous, structural members are required and where space is at a premium; for counter-balancing purposes where space is limited and where design considerations dictate an increased weight per unit volume; and as a shielding material for X-rays, radium and secondary radiation products.

Samples of the metal were placed in the pile at the Oak Ridge Atomic Energy Research Establishment, and preliminary measurements have indicated two primary irradiation products: tungsten—187 with a twenty-four-hour half-life, and Tungsten—185 with a seventy-four-day half-life. These measurements indicate that the metal will make an excellent shield for either beta or gamma radiation. However, low intensity neutron bombardment should cause only moderate activity, and alpha radiation will introduce only a small amount of activity. It is expected that the material will find usage for isotope storage, and as a general space-saving, shielding material for betatron, synchrotron or cyclotron radiation of high efficiency. The following table gives the physical properties of the metal:—

Hardness:	
Rockwell	"C" 24–30
Brinell	250–285
Ultimate tensile strength (average)	105,000 lb per square inch
Yield strength (0·2 per cent offset)	75,000 lb per square inch
Proportional elastic limit	25,000 lb per square inch
Modulus of elasticity	40,000,000 lb per square inch
Elongation (per cent in 2in)	2·5
Modulus of rupture (average)	205,000 lb per square inch
Endurance limit (rotating beam)	40,000 lb per square inch
Electrical conductivity	14 per cent I.A.C.S.
Thermal coefficient of expansion (−68 deg. Cent. to 900 deg. Cent.)	0·0000071in per inch per degree Centigrade

An instrument for determining the hydrogen content in metals was introduced to the industry at the stand of the National Research Corporation, of Cambridge, Massachusetts. According to the firm, the speed of this so-called "NRC Hydrogen Analyser" enables it to be employed effectively as a production control device while its accuracy makes it suitable for laboratory work. As evidence has been accumulated showing that many steel failures due to porosity and embrittlement are caused by high hydrogen content at the time of pouring, the need for a rapid and quantitative means of measuring the hydrogen content has become apparent. Recognising this need, Dr. John Chipman, Dr. N. J. Grant and their co-workers at the Massachusetts Institute of Technology, developed the

"Tin-Fusion Method for the Determination of Hydrogen in Steel" and the "Thermal Conductivity Method for Analysis of Hydrogen in Steel." The combination of these two methods has resulted in the development of the present instrument. The steel sample is melted with tin under high vacuum, the evolved gas is collected and the hydrogen content is determined by measuring the thermal conductivity of the evolved gas. Basically, the instrument is similar to the "NRC Vacuum Fusion Gas Analysis Apparatus," but it differs in that the "NRC Hydrogen Analyser" is designed especially for rapid hydrogen determination.

Because the analysis can be run rapidly, the unit can be used for melting shop production control. It is claimed that fifteen minutes is the total time necessary to prepare and test a sample, of which ten minutes is the actual testing time.

Arc Welding

One of the more interesting developments in the field of arc welding was the initial demonstration by The General Electric Company, of Schenectady, New York, of its "Fillerarc" process and equipment, which constitutes that firm's entry into the consumable-electrode, gas-shielded welding market. The introduction of the "Fillerarc" apparatus is expected to broaden the field of application in America of high-speed, high-current-density, gas-shielded arc welding which so far had been restricted to a certain extent by the necessity of using existing welding generators not specifically designed for this particular process. It is claimed that the high-speed metal deposition provided by the new equipment enables the operator to more than double his output on applications where filler metal has to be added to the parent material. Furthermore, the equipment is said to simplify control, to decrease operator training time, and to reduce operating and maintenance costs. Electrode wire of aluminium, stainless steel, mild steel, copper and other alloys may be employed in the equipment with argon or helium shielding gas. The process can be used in down-hand, vertical or overhead positions to weld aluminium alloys in thicknesses from $^{1}/_{32}$in to 3in and stainless steels from $^{1}/_{16}$in to 1in. It has also been found suitable for welding aluminium-bronze, nickel and magnesium. The "Fillerarc" welding equipment consists of three main components : a self-regulating motor generator welding set, a pistol-like holder and an electronic wire-drive unit.

The "Fillerarc" welding generator is rated at 450A continuously and has a rising volt-ampere characteristic. As current is produced by the set, the voltage generated increases, making the welding process completely self-regulating. Designed to give constant arc length, the unit produces any current required up to its full rating. Thus, it is prepared for any wire feeding speed and will supply the current necessary to melt off the wire at length only. Once the arc length is set, the operator can change the wire feed (the only other variable to be controlled) even while welding, without the necessity of readjusting the set. The open circuit voltage of the generator is between 10V and 30V and will not sustain long arcs, thus greatly reducing the possibility of "burn-back." It will not change its setting during operation and therefore makes unnecessary the use of elaborate feed-back controls generally required for fully-automatic welding.

The welding gun contains knurled feed rolls for pulling the electrode wire from a spool mounted in the wire drive unit, a trigger to control wire feed and gas flow, and an electrical contact tip. It is water cooled and has a rating of 450A continuous d.c. The gun is capable of feeding wire from 0·30in to 0·93in in diameter and has no special temperature requirements. The hazard of kinked electrode wire is eliminated due to the wire being "pulled" instead of "pushed" through the gun. Thus, smaller diameter wire can be used with the equipment, greatly increasing its range of application. The wire feed speed can be adjusted from 0in to 750in per minute by means of a remote two-speed switch, and the set speed is held constant by an electronic motor control in the wire drive unit. A finger-tip control enables the operator to obtain gas coverage automatically before and after the arc is struck. It also makes possible welding without holding the trigger depressed. In operation, the gun is positioned, the trigger is pulled to get preliminary gas coverage, and is then released to feed wire. The arc is automatically started as the wire touches the work. Operating the trigger again stops the wire feed, and the gun is held in place over the work to provide gas coverage as the weld cools. As the wire stops feeding, the arc current is reduced to zero, the generator voltage drops and the arc goes out without burning back to the gun.

The "Fillerarc" wire-drive unit is mounted on a portable carriage and contains a "Thy-motrol" wire feed drive motor control which powers the knurled feed rolls in the welding gun through a flexible shaft. It incorporates a voltmeter for indicating the wire feed speed in inches per minute as well as the arc voltage, a gas solenoid valve, control relays and a spindle for the electrode wire. The spindle handles spool or rim-wound wire up to a mile long and has a solenoid brake that prevents over-running of the reel and entangling the wire when not welding. Dynamic braking also provides that at the end of a weld the wire projects from the nozzle of the gun by just the correct length for the next start so that it does not need to be trimmed with pliers.

An indication of the increasing acceptance of Shielded Inert Gas Metal Arc, or "SIGMA" welding in America is the development of a completely automatic welding machined based on this process by the Linde Air Products Company. The machine, known as the "SWM-3," was demonstrated at the "Metal Show" depositing copper for build-up purposes. This latest of the fusion welding processes is now being used on practically all commercial metals. Among its recent applications are railway tank wagons, chemical and food processing tanks, pressure vessels and brewery equipment. All weldable grades of aluminium, including the American 3-S, 50-S (150-S), 52-S, 61-S and the commercially pure 2-S alloys are being welded with excellent results. They are being machine-welded in thicknesses ranging from 0·50in to 1·50in, and hand welds are being made in material of $\frac{1}{4}$in minimum thickness. In stainless steels, sound butt welds have been obtained in thicknesses ranging from $\frac{1}{8}$in to $\frac{1}{2}$in, and results of tests show that the welds possess good tensile strength, elongation, corrosion and impact resistance. Sound butt, fillet and corner welds have been made in $\frac{1}{4}$in to 1in thick deoxidised copper and butt welds made in $\frac{1}{8}$in, $\frac{1}{4}$in and $\frac{1}{2}$in thick "Everdur" (a copper-silicon-manganese alloy) have been found to be sound, smooth and without cracks or under-cutting. Sound machine butt welds have been made in $\frac{1}{8}$in, $\frac{1}{4}$in and $\frac{1}{2}$in thick killed and semi-killed carbon steels, and aluminium bronze rod has been deposited on mild steel with excellent results. Other surfacing and build-up operations, including stainless steel, copper and "Everdur" deposits on mild steel, have proved successful.

The "SWM-3" welding machine feeds welding wire from a coil into the weld at a steady, automatically controlled rate. It maintains a continuous blanket of inert gas that shields the weld zone from contamination by the atmosphere. The unit can be used for d.c. welding, of either straight or reversed polarity, but cannot be used for a.c. welding. It has an electronic arc voltage control which holds the arc voltage substantially constant at any preset value in the welding range. This unit speeds up or slows down the feeding rate of the welding wire, instantaneously compensating for changes in arc voltage due to any uneven burn-off of the welding wire so that the operator does not have to exercise judgment or divert attention from the work itself. An automatic arc cut-off shuts down the machine (1) if the wire becomes tangled ; (2) at the end of the coil, or (3) if the arc runs off the end of the work.

The machine has provisions for retract or scratch starting. In retract starting, welding wire feeds down until it touches the work, then retracts, thus drawing the arc. In scratch starting, welding wire feeds down while the welding head moves along until the rod scratches the work and strikes an arc. In either case the welding wire is finally fed down again to maintain the pre-set arc voltage. The welding wire itself is wound on rims or spools. The use of a continuous coil of wire means that welding does not have to be frequently interrupted to install a new wire in the torch. The welding wire can, however, be readily changed from one to another of four different sizes—$^{1}/_{32}$in, $^{3}/_{64}$in, $^{1}/_{16}$in and $^{3}/_{32}$in diameter. The wire feed motor is controlled to drive the wire at the speed required to maintain the pre-set value of welding arc voltage, and a wire straightening device straightens the welding wire and centres it in the shielding gas stream. Thus the weld is always fully shielded from the air, making flux unnecessary and minimising any spatter.

The Lincoln Electric Company, of Cleveland, introduced and demonstrated an interesting new product this year : "Jetweld"—a shielded-arc welding electrode with a coating containing a powdered metal constituent. The electrode was designed to facilitate fast and easy operation in flat and near-flat positions with a.c. or d.c. welding. The powdered metal present in the electrode coating is claimed to make the welds crack-resistant and to provide impact resistance properties not found in conventional electrodes. According to the company, the new electrode has higher deposition rates, yet operates at lower currents than other electrodes. "Jetweld" meets the physical requirements of the American A.W.S. class "E-7016" specification and is now being used on work formerly calling for E6012 and E-6020 electrode on single-pass or multiple-pass welds. It has been found especially suited for : (1) horizontal and flat-position fillet welds ; (2) horizontal and flat-position lap welds ; (3) single and multiple-pass butt welds ; (4) deep grooves and corner welds ; (5) cover passes on multiple-pass butt welds. The electrode is said to be ideally suited for welding, without cracking and without surface holes, of higher-carbon steels, which are normally welded with electrodes other than the low-hydrogen types.

D.c. welding is performed with the electrode polarity being positive, but a.c. welding is recommended for obtaining a smoother arc, easier slag removal and a higher arc speed. A drag technique is used and the electrode is held into the fillet with pressure being applied against both legs of the fillet. The angle of electrode should be 45 deg. with the horizontal and leading away from the weld at 30 deg. to the vertical. The travel speed is maintained so that the arc is $\frac{1}{4}$in to $\frac{3}{8}$in ahead of the puddle. The following table lists some typical welding currents and speeds obtained with the electrode.

Typical Welding Currents and Speeds with "Jetweld" Electrode

Electrode size, inch	Current, Amps.	Polarity	Fillet size, inch	Arc speed, inches per minute
$\frac{1}{8}$	225	A.c.	$\frac{1}{4}$	15·0
$\frac{1}{8}$	200	D.c. (+)	$\frac{1}{4}$	12·5
$\frac{5}{32}$	275	A.c.	$\frac{5}{16}$	15·0
$\frac{5}{32}$	250	D.c. (+)	$\frac{5}{16}$	12·5
$\frac{1}{4}$	350	A.c.	$\frac{3}{8}$	14·0
$\frac{1}{4}$	300	D.c. (+)	$\frac{3}{8}$	12·0

Every year one continues to notice progress in the field of non-destructive testing and, at the exhibition, both the Magnaflux Corporation, of Chicago, and Sperry Products, Inc., of Danbury, Connecticut, showed their respective ultrasonic inspection equipment. A useful application of ultra-sonic principles to facilitate the cleaning of metal parts was demonstrated by the Topper Equipment Company, of Rahway, New Jersey, introducing its "Circosonic" degreasing machine. The unit offers a method of removing oil, grease, chips, dirt, lapping compound and many other contaminants from the surfaces of small precision work-pieces at a high production rate and to a high degree of cleanliness. The degreasing is accomplished by beaming a high-frequency sound wave through the cleaning solvent or detergent solution to the surface of the submerged work-piece. The sound wave, which is usually in the range of 300kc/s to 750kc/s, is set up directly in the liquid cleaning bath by means of a vibrating quartz crystal. The crystal, in turn, is driven by an electronic oscillator.

The cleaning machine consists of a General Electric ultrasonic generator with the addition

of suitable conveyor equipment. The lower cabinet of the machine contains an electronic generator. The cleaning process takes place within the upper cabinet, which houses the conveyor chain and drive motor, the treating tank and the electro-acoustic transducer. A cylindrical stainless steel housing for the crystal has been used in preference to a plastic housing because of the incompatibility of plastics and the common chlorinated hydrocarbon solvents. The upper surface of the crystal is covered by water or a weak salt solution, which is supplied from a small cylindrical reservoir in front of the housing. The motion of the crystal sets up the sound wave in the salt solution: the wave passes upward through an acoustic window into the trichlorethylene flowing in the treating tank, where the cleansing action takes place.

As in the U.K., the use of radioactive isotopes for weld inspection is continuing to increase in the United States, and displayed at the booth of Tracerlab, Inc., of Boston, was a comprehensive set of testing equipment, including cobalt-60 and iridium-192 source capsules, source containers, magnetic remote handling gear, and monitoring and personnel safety equipment. At the present time, cobalt-60 sources are available from the company with nominal strengths ranging from 50 millicuries to 25 curies. The specific activity of the isotope, as now available from the U.S. Atomic Energy Commission, is approximately 20 curies per cubic centimetre, as compared to approximately 2 curies per cubic centimetre for the usual radium sources. This increased specific activity makes possible the use of more intense sources without increasing the source dimensions, or permits the use of sources of the same intensity as radium sources, but of a smaller physical size. In the first case, the exposure time may be decreased for a given exposure set-up, and in the second, better definition may be obtained without increasing the exposure time. The absorption coefficient of cobalt-60 gamma rays, and thus the exposure time, is very closely comparable to that of radium. Cobalt-60 gamma ray energies are sufficiently far above those of maximum scatter to give good radiographic sensitivity and to eliminate the need for complicated blocking and filtering. One of the great advantages provided by cobalt-60 radiography is the portability of the equipment needed to make successful exposures, contrastly with the relative inflexibility of X-ray installations. In many instances the cobalt-60 capsule, its shielding container, magnetic handling gear, and film cassettes are now taken directly to the construction site where inspection may be made of work in progress, such as steel frame weldments, large pipe-laying projects and chemical processing equipment.

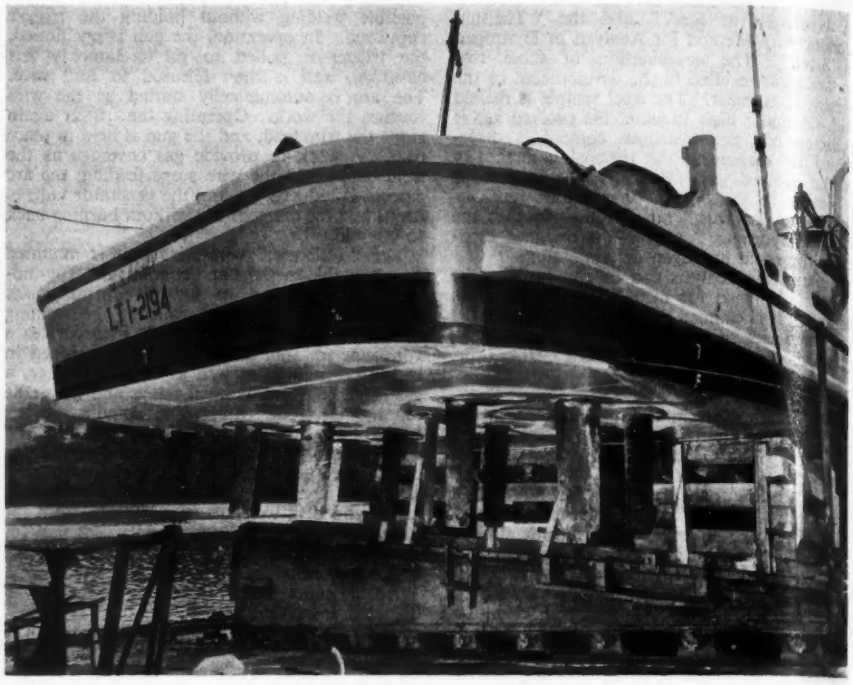
American Engineering News

(By Our American Correspondent)

Towboat Application of Sinusoidal Vertical Axis Propellers

A demonstration took place recently on the Ohio River near Pittsburgh of an experimental "LTI-2194" (large towboat, inland waterways) vessel, which was built for the Transportation Research and Development Command of the U.S. Army by the Dravo Corporation, of Pittsburgh. The 150ft vessel, shown on this page prior to launching, obtains its exceptional manœuvrability by virtue of being able to deliver thrust with equal effectiveness in any direction. The craft has no rudders and uses two sinusoidal vertical axis rotors in place of conventional horizontal axis screw propellers. The rotor discs are about 11ft in diameter and each carry six manganese bronze blades, which are 4ft 6in long.

The development of this river towboat is a major part of the current American Transportation Corps Inland Waterways Fleet programme to develop equipment for use on waterways throughout the world. The "LTI-2194" was designed to operate on the principal rivers of the world and, although its characteristics are mainly those of a river towboat, several aspects make it suitable for navigation in waters which are not completely sheltered. An important factor influencing its design was the requirement for manœuvring heavily laden barges with positive control in restricted and swift-flowing rivers. Research conducted by the Transportation Corps indicated that "push-towing," as now practised on the rivers of the United States, is the most practical and efficient way to move barges. Vertical axis propellers were considered to be the answer to the problems of manœuvrability and control, based on observations of their use in other craft. The Transportation Corps believes that this new experimental vessel will be of interest also to commercial operators in America because it is the first river towboat to be equipped with vertical axis propellers in this country.



Vertical Axis Propellers of L.T.L-2194 Craft

Each of the two vertical axis propeller units weighs approximately 22 tons and fits into circular openings in the stern of the boat. The units are readily accessible from the stern deck for repair and maintenance, and the blades can be replaced without dry docking the boat. The craft is powered by two twelve-cylinder, turbo-supercharged Cooper-Bessemer diesel engines rated at 1000 s.h.p. each. The engines are connected to the rotors through double reduction gears, which are built into the propeller assembly. The rotors turn at 76 r.p.m. when the engines operate at their rated top speed of 900 r.p.m. Variations in thrust are obtained by adjusting the engine speed, while the blades are automatically pitched for maximum efficiency. Each blade is connected by a rod to an eccentric ring situated around the rotor shaft, and the movement of this ring changes the pitch of all six blades. For purposes of steering and flanking the entire eccentric ring assembly is turned to alter the direction of thrust in any direction around a 360 deg. circle. The vessel is of all-welded steel construction with a beam of 32ft and a normal draught of 7ft. It is designed for a non-stop operating range of 1200 miles: 600 miles upstream against a 5 m.p.h. current, and 600 miles downstream. The "LTI-2194" is equipped for pull-towing as well as push-towing. In addition to steel towing "knees" built integrally with the bow, there is also provided a power capstan and accessory equipment aft for pull-towing on a hawser.

Investigation of Terrestrial Electrical Fields

The Minneapolis-Honeywell Regulator Company, of Philadelphia, has announced the development of a so-called "aerial electrometer." The instrument is an extremely sensitive electronic device which will be used in an investigation of terrestrial electrical fields by the Research and Development Command of the U.S. Air Force. This determination of the nature of electrical currents which exist between the earth and the upper stratosphere is believed to affect interplanetary flight and to be highly important to long-range wireless communications. It has been found that there exists between the earth and the ionosphere an electric potential in excess of 100kV. Until now it had been possible for the U.S. Air Force to collect data on this atmospheric electricity only by means of instruments carried by aircraft up to altitudes of 35,000ft. The new instrument will be carried aloft by balloons as high as 100,000ft, and such tests are already being conducted at the Holloman Air Development Centre at Alamogordo, New Mexico. According to official sources, this research project is part of a continuing study being made of the terrestrial electrical field existing between the earth and the ionosphere. It is hoped that the data to be obtained from the current phase of the research programme will lead to an understanding of the current of 1800A constantly flowing toward the earth.

The sensitive electronic device to be used in the experiments was designed and developed in the Nuclear Engineering Laboratory of the company. It weighs only 6½ lb, is the size of a portable wireless set, is powered by batteries and is packed with sub-miniaturised electronic parts. An aluminium case with special insulation has been provided to minimise the problems due to solar radiation and low temperatures found at high altitudes. According to the firm, the instrument is so sensitive that it will measure flows of electric current as low as one-ten-millionth of a millionth of an ampere, or one million ions per second. When carried aloft by large plastic, free-flying balloons the instrument instantaneously transmits back to a ground recording station the prevailing values of electrical conductivity, air temperature and air pressure. By interpreting the temperature and pressure readings it will be possible to determine accurately the altitude of the instrument, thus obtaining a record of the variation of the electrical conductivity with the altitude. Upon reaching maximum height the balloon is mechanically broken and the apparatus parachuted to the ground.

LEVERHULME PRIZE AWARD.—The Leverhulme Prize for cost accountancy in the December, 1953, examination of the Institute of Cost and Works Accountants has been awarded to Mr. Michael P. Rydon, of Port Elizabeth, South Africa.

Industrial and Labour Notes

Engineering and Shipbuilding Wages

Last Friday, H.M. Stationery Office published the two reports of the Courts of Inquiry which were appointed by the Minister of Labour on January 1st to investigate the wage disputes in the engineering and shipbuilding industries. Both Courts had the same membership with Lord Justice Morris as chairman, and although there are two reports, one for the engineering industry and one for the shipbuilding industry, the conclusions and recommendations are similar in essential details.

The principal recommendation made by the Courts is that there shall be a resumption of negotiations between the Engineering and Allied Employers' National Federation and the Shipbuilding Employers' Federation, on the one hand, and the Confederation of Shipbuilding and Engineering Unions, on the other. The Courts say in their reports that, although they do not each attach the same weight to the various considerations which were put before them, they are agreed that there is justification for some increase in consolidated time rates, but "not to the extent claimed." The "extent claimed," it will be recalled, was 15 per cent for adult male workers in both industries, which claim was rejected by the employers' federations. It is suggested in the reports that the parties themselves can best arrange the amount of any increase, but as a "pointer," which, it is hoped, will assist, the Courts take the view that an increase should be "something in the region of one-third of the amount claimed." A 5 per cent increase on the existing time rates in both industries would amount approximately to 7s. a week for skilled men and slightly less than 6s. a week for unskilled men. The report dealing with the engineering wage dispute urges that consideration should be given to the setting up of some joint body which could keep wages and related matters under review, and to which preliminary negotiations on national wages questions might be delegated without the formality of the large meetings and elaborate recording of proceedings which have characterised negotiations between the parties in recent years. It is suggested that such a body might usefully consider a simplification of the engineering wages structure, which was recommended by a Court of Inquiry in 1948, but with which little progress has been made.

The executive council of the Confederation of Shipbuilding and Engineering Unions met on Monday last to discuss the reports, and decided to ask the employers for a resumption of negotiations. The committees of the two employers' federations were due to meet later in the week to consider the reports.

Industrial Production

It has now been calculated by the central statistical office of the Treasury that industrial output in the United Kingdom last year was 5½ per cent higher than in 1952 and 2½ per cent higher than in 1951. The index for all industries in December last (1948=100) was 120, compared with 112 a year earlier. Taking the manufacturing industries alone, the index number for December, 1953, was 122, against 113 a year earlier. In mining and quarrying the December, 1953, number was 108, compared with 104 in December, 1952. The central statistical office says that, on the basis of information so far received, the index for January is likely to be 126 or 127, which will bring it 8 points above the record January figure achieved in 1953.

Recent developments in the productive strength of the United Kingdom were referred to by the Chancellor of the Exchequer, Mr. R. A. Butler, when he presided over a meeting of the National Production Advisory Council on Friday last. He said that there had been a considerable increase in capacity over recent years for the production of many things of vital interest to the Commonwealth, such as steel, contractors' plant, electrical plant and heavy track-laying tractors. Taken as a whole, however, the output of all kinds of plant and machinery was slightly lower in 1953. Summing up the production record of 1953, the Chancellor said that there had been a general recovery in the consumer trades accompanied, after a sluggish period, by some signs of a renewed upward movement for engineering goods, together with a further growth in building work.

The important question for 1954, the Chancellor continued, seemed to be whether United Kingdom industries were sufficiently competitive in all respects to secure a sufficient volume of business overseas. Much of last year's progress had been due to a few industries, such as refined petroleum, aircraft and arms and ammunition, which did not face German competition, but in other industries that competition was being strongly felt. Exports of cars, commercial vehicles and of machinery as a whole were down, and, although towards the end of last year there was some improvement in our exports, we were still losing ground to our competitors in some respects. Whereas this country's engineering exports showed a 4 per cent rise in value between the second half of 1952 and the second half of last year, German engineering exports had risen by 12 per cent. There was no doubt, the Chancellor added, that price played an important part in that, and it was possible that the Germans were willing to accept some orders at a loss in order to secure the business. But, the Chancellor went on, it would be wrong to infer that United Kingdom export prices had become generally uncompetitive, for if they had the rise in exports last year could not have been achieved. There were, however, some other factors which would have to be watched. For example, the Chancellor said, if there was no recovery of production in the U.S.A. this year, the struggle for export markets was bound to become still keener. It was satisfactory that our gold and dollar reserves had continued to rise during the period of the decline in American productive capacity, though the rise in reserves was at a slower pace than previously and, in the last few months, United Kingdom exports to North America had fallen. Future demand for United Kingdom exports, the Chancellor emphasised, would depend partly on the level of world demand, and also on what British industry did to increase its competitive power.

Changes in Wage Rates

The Ministry of Labour has stated that, in the industries covered by its statistics, the changes in wage rates which became effective in January resulted in an aggregate increase estimated at about £164,000 in the weekly full-time wages of 714,000 workpeople. Among those receiving increases were workpeople employed on the road transport of goods, bus and trolleybus drivers, conductors and maintenance staff employed by London Transport, workers in a section of the heavy chemicals industry, and those employed in waterworks undertakings in England and Wales.

Trade Disputes

The number of stoppages of work through industrial disputes, which were reported to the Ministry of Labour as beginning in January, was 177. In addition, there were still in progress in the early days of the month ten stoppages which had begun prior to January. The Ministry of Labour says that in these 187 stoppages 51,900 workpeople were involved in January, with the result that 128,000 working days were lost. In January last year, there were 143 stoppages through disputes, involving 25,700 workpeople and causing an aggregate loss of 67,000 working days.

Tungsten Ores

The Minister of State, Board of Trade, Mr. Heathcoat Amory, announced in the House of Commons last Monday that the Government had decided to restore private trading in tungsten ores and concentrates on April 1st. That decision, he said, had been taken after consultation with the trade. The Minister went on to explain that private imports from all sources except the dollar area would be permitted from that date. In order to ensure a smooth transition from public to private trading, however, and so that surplus stocks held by the Ministry of Materials might be disposed of with the minimum amount of disturbance to the market, arrangements were being made by which, during the early months of private trading, consumers would continue to meet a substantial part of their requirements by purchases from the Ministry's stocks. Mr. Amory said that the Ministry of Materials would shortly be communicating with consumers individually about the detailed application of the arrangements.

T.U.C. Representations on the Budget

The general council of the Trades Union Congress has submitted to the Chancellor of the Exchequer some representations concerning the forthcoming Budget. Its statement on the matter says that Britain's economic position is still fundamentally precarious, and that as a nation we are still not earning enough to pay our debts, build up our reserves and meet our investment obligations abroad. The terms of trade, the T.U.C. suggests, are unlikely to continue to swing in this country's favour, and the full impact of foreign competition has yet to be felt in the export markets.

The statement by the T.U.C. goes on to say that Britain's economic objectives must rise above the "present uncertainties," and it is urged that there must be an increase in exports, investment, production and productivity. Action through the Budget alone, it is claimed, is not enough, for the T.U.C. view is that "as the problem is largely one of sharing limited resources between competing needs other measures are required, including a greater degree of direct control over the economy." All the claims on our resources, it is added, including the needs of defence and consumption as well as of exports and investment, can ultimately be satisfied by higher production and productivity. Production of the right goods must therefore be stimulated, the T.U.C. says, and the foundations must be laid now for further increases in efficiency. Although production in general rose last year it was not concentrated where it was most needed—that is, in the capital goods and export trades. Budgetary action, therefore, the T.U.C. says, should concentrate on putting first things first, which means accepting the need, where necessary and practicable, to encourage exports at the expense of the home market and to encourage investment at the expense of increased consumption.

Coal Production

In the first eight weeks of this year, coal production in Great Britain totalled 36,808,600 tons, compared with 36,745,200 tons in the corresponding period of 1953. A statistical statement issued by the Ministry of Fuel and Power shows that the improvement has been effected by increased production from the deep mines. Last week's output amounted in all to 4,666,600 tons, of which 4,464,600 tons came from the deep mines and 202,000 tons from opencast workings. The amount of deep-mined tonnage lost last week through disputes has been estimated at 23,300 tons. Manpower in the mines shows a steady improvement, the number of workers on colliery books on February 20th being 709,300, of whom 291,700 were face workers. A year ago, however, the number on colliery books was 716,600. Absenteeism in the week ended February 20th was put at 12·98 per cent, which showed an improved attendance compared with several preceding weeks. Total distributed stocks of coal on February 20th were 14,208,000 tons, compared with 13,152,000 tons on the corresponding date last year.

Notes and Memoranda

Rail and Road

ROAD FUND REPORT, 1952–1953.—The latest report on the administration of the Road Fund, covering the year ended March 31, 1953, presents in some ways a more complete and up-to-date picture of road expenditure than reports for previous years, it is stated, by the Ministry of Transport and Civil Aviation. Total expenditure on roads and bridges during the year 1952–53 was about £86,000,000, an increase of £5,000,000 on the previous year. Of this sum, nearly £32,000,000 was borne by the Road Fund and the balance by local highway authorities. Most of the money was used for maintenance and minor improvement, but £6,000,000 was spent on major improvements and new construction work, thus maintaining expenditure under this heading at about the same level as in the preceding year. The report gives details of major improvements of trunk roads in progress during the year and of the by-passes and diversions, the lines of which have been fixed by Orders. New or improved systems of street lighting were provided on 77½ miles of trunk roads at a cost of about a quarter of a million pounds, half of which was contributed by the Ministry. Among the more important improvement schemes begun during the year was the building of a new bridge over the River Itchen at Northam, Southampton, the cost of which is estimated at nearly half a million pounds. The report is published by H.M. Stationery Office, price 2s. 6d.

Air and Water

SEAWARD DEFENCE BOAT.—On Tuesday of this week Her Majesty's seaward defence boat " Aberford " joined the fleet upon completion by her builders, Yarrow and Co., Ltd. The ship, which has an extreme length of 117ft 3in and a water line length of 110ft and a beam of 20ft, is powered by diesel machinery manufactured by Davey, Paxman and Co., Ltd.

DOCK AND HARBOUR BOARD AUTHORITIES' ASSOCIATION.—At the annual general meeting of the Dock and Harbour Board Authorities' Association, which was held in London last week, Sir Douglas Ritchie, the vice-chairman of the Port of London Authority, was elected president in succession to Colonel J. G. B. Beazley, and Sir Leslie Roberts was appointed chairman of the executive committee.

H.M.S. " DIANA."—We are informed by the Admiralty that H.M.S. " Diana," the last of the eight " Daring " class ships, is expected to join the fleet on March 19th. The ship, which was launched on May 8, 1952, is of all-welded construction and was built and engined by Yarrow and Co., Ltd., and has an overall length of 390ft, a length between perpendiculars of 366ft, a beam of 43ft, and is armed with six 4·5in guns.

LAUNCH OF H.M. SUBMARINE.—The Admiralty announces that the first submarine to be launched for the Royal Navy since the completion of the " A " class submarines in 1948, is to be launched to-day from the Barrow yard of Vickers-Armstrongs, Ltd. The ship, H.M.S. " Explorer," has an extreme length of 225ft 6in, a length between perpendiculars of 178ft, a beam of 15ft 8in, and is being fitted with the latest submarine escape arrangements, including a one-man escape chamber.

LAID-UP SHIPPING.—We are informed by the Chamber of Shipping that, on January 1, 1954, fifty British ships of 213,715 tons were laid up at ports in Great Britain and Northern Ireland, for reasons other than repair, compared with forty-one ships of 93,051 gross tons a year ago. The total of ships awaiting or undergoing repair was eighty-two of 408,828 tons, compared with 108 ships of 652,588 tons on January 1, 1953. Foreign ships awaiting repair at British ports numbered six, of 31,658 tons, whereas one year ago the total was fourteen ships of 87,591 tons.

OBITUARY.—We record with regret the death of Mr. Charles Nicholson, O.B.E., which occurred at his home on Saturday of last week. Mr. Nicholson, who was eighty-five at the time of his death, has been for many years one of Britain's leading yacht designers and was responsible for many famous yachts, including " Shamrock IV " and " Endeavour," which were challengers for the America's Cup. Apart from racing yachts, Mr. Nicholson was interested in the evolution of the motor yacht, and one of these, the " Philanti," designed in 1937, is now the Norwegian Royal Yacht " Norge." Mr. Nicholson was the first Freeman of Gosport and a liveryman of the Worshipful Company of Shipwrights.

Miscellanea

IRON AND STEEL HOLDING AGENCY.—The Treasury has made an Order under the Iron and Steel Act, 1953, prescribing September 30th as the date on which the Iron and Steel Holding and Realisation Agency's financial year shall end. It provides also that the Agency's first financial year shall be the period from July 13, 1953, to September 30, 1954.

INDUSTRIAL DELEGATION TO BURMA.—The president of the Board of Trade announced in Parliament last week that a delegation of industrialists from this country is to visit Burma this month. The delegation will be led by Lord Burghley, the other members being Mr. H. Nimmo, M.I.E.E., Brigadier M. Pearce, Mr. W. H. Sharp, Mr. K. H. Tuson, M.I.Mech.E., and Mr. G. P. Brownie. The delegation will discuss the Burmese Government's long-term plans for developing the resources of the country and will consider how British industry can best contribute to those plans.

KENT REFINERY'S LABORATORY.—At the Kent Oil Refinery on the Isle of Grain a new laboratory has been completed, consisting of sixteen separate laboratories grouped into two sections, production control and process development. All the services are on a centralised system and warming of the building is by dust-free heated air.

REFINERY CONTROL.—The Aden refinery, of 5,000,000 tons capacity, which is under construction for the Anglo-Iranian Oil Company, Ltd., is to have its crude oil distillation units electronically controlled. An air conditioned control room is to be built, overlooking the distillation unit, and from it an operator will regulate the flow pressure, level and temperature of the various oil streams.

DEVELOPMENTS IN STEEL TECHNOLOGY.—The steel committee of the United Nations' Economic Commission for Europe has produced a report recording some of the developments last year in iron and steel technology. The report is in three sections dealing respectively with pig iron production and blast-furnace practice ; steel-making, with particular reference to the use of oxygen, and rolling and finishing processes.

MONOPOLIES COMMISSION.—The Board of Trade has announced the appointment of three further part-time members of the Monopolies and Restrictive Practices Commission. The new members are : Mr. James Archdale, executive director of James Archdale and Co., Ltd.; Mr. Brian Davidson, commercial director of Bristol Aeroplane Company, Ltd., and Mr. C. E. Wrangham, director of G. Tennant Sons and Co., Ltd.

HYDRAULIC RAM PROTECTION.—A brochure entitled " Hydraulic Efficiency," has been prepared by Fescol, Ltd., North Road, London, N.7, describing some of the applications of the " Fescol " process to high pressure hydraulic rams. It contains an article by C. C. Harris, of the Hydraulic Engineering Company, Ltd., Chester, describing the advantages of this process of depositing nickel or chrome on rams in hydraulic systems using oil or water.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE.—The West of Scotland Iron and Steel Institute has just published a special issue of its *Journal*. In addition to a selection of the papers presented to the Institute during the 1952–53 session, the *Journal*—which is numbered Volume 60—contains a full report of the conference on " Brittle Fracture in Steel," which was held last May. The price of the volume is £2 10s., and copies can be obtained from the Institute at 39, Elmbank Crescent, Glasgow, C.2.

LOCOMOTIVE WORKS' APPRENTICESHIP SCHEMES.—The North British Locomotive Company, Ltd., Springburn, Glasgow, N., has three apprenticeship schemes in its works, one for trade apprentices, a second for engineering apprentices, and a third for university apprentices. A brochure has already been published by the firm dealing with its trade apprenticeship scheme, and it has now issued an interesting booklet entitled " Engineering as a Career," in which the training and opportunities available for engineering and university apprentices are dealt with in some detail.

240FT BAILEY BRIDGE FOR TURKISH GOVERNMENT.—A £30,000 contract to build a 240ft Bailey bridge for the Turkish Government has just been completed by Thos. Storey (Engineers), Ltd. The bridge is an access bridge for the Seyhan dam project now under construction to provide irrigation and power for the area around Adana in Southern Turkey. Under the firm's supervision, the bridge was built by American engineers and a Turikshi construction crew in two weeks. It has three spans and a 30ft roadway capable of carrying 40-ton Euclid trucks or one 90-ton Lima shovel.

" DELEGATION OF AUTHORITY."—A booklet entitled " Delegation of Authority " has been published, at 2s., by the Industrial Administration Group of the College of Technology, Birmingham. It contains the text of a lecture to graduate students of industrial administration at the college, which was delivered by Mr. John Raymond, managing director of Chance Brothers, Ltd. The lecture dealt mainly with the personal problem of delegating authority, Mr. Raymond pointing out that unsuccessful delegation of authority directly affected productivity, as managerial efficiency and productive output were indivisible.

CONTINENTAL REFINERIES.—Following the completion of acid and clay treatment plants, the Porto Marghera refinery, Venice, is expected to produce 15,000 tons a year of lubricating oils. Additional units will be commissioned at other refineries operated by the Anglo-Iranian Oil Company, Ltd., and its associates, including a new distillation unit at B.P. Hamburg, to raise the refinery's annual capacity to 1,240,000 tons, and also a 250,000 tons per year platformer ; while at the nearby Schindler refinery a new furfural treating plant is being installed to raise lubricating oil production to 35,000 tons per annum.

NATIONAL DIPLOMA IN AGRICULTURAL ENGINEERING.—The final examination for the National Diploma in Agricultural Engineering will be held on the four days July 20th to 23rd next, followed by the oral examinations on July 27th. Entry forms may be obtained from the secretary of the Institution of British Agricultural Engineers, 24, Portland Place, London, W.1, the closing date being April 14th. The submission of entries prior to this date, however, would be appreciated. The entrance fee of £10 10s. must accompany the entry form. The names of the colleges approved for providing the necessary training may be obtained from the secretary of the Institution of British Agricultural Engineers.

PUBLIC WORKS IN VENEZUELA.—The January edition of *Venezuela Up-to-Date*, a journal published by the Washington Embassy of Venezuela, contains some information on public works completed in Venezuela in 1953. Projects including highways, public buildings, hospitals, water supply, electrification, and housing and welfare schemes totalling about 265 million dollars, were completed in 1953 and inaugurated during the week November 24 to December 2nd last, which was the first anniversary of the President, Perez Jimenez. The most important of these public works is the Caracas-La Guaira motorway, which was described in our issue of January 22nd. Altogether thirty-one road projects, totalling 800 miles of highways, were inaugurated, the journal states ; thirty-nine new electric plants were completed, as were 107 new water supply systems, thirty-five hospitals and sixty public buildings, as well as schools and houses. At airports and ports, eight projects, including surfacing of runways, were completed, and a new seaport was dedicated at Paraguana. A dredging scheme on the Orinoco River, undertaken by the Bethlehem Steel Corporation, was amongst the projects completed.

DIFFRACTION GRATINGS IN INDUSTRY.—For some time the National Physical Laboratory has been developing a new method, suggested by Sir Thomas Merton, for making diffraction gratings. Although primarily intended as components of spectroscopes for analysing radiation, the " Merton-N.P.L." gratings are finding a very useful application in industry. They can be used for precise measurement of length and the control of machine tools. For these purposes long, accurate transparent gratings are needed. By the new process they can be produced quite cheaply. If two of these gratings are placed one upon the other with their rulings inclined at a small angle dark lines or fringes are produced. They run at right angles to the rulings, and resemble the " moiré " effect of watered silk. If, now, one of the gratings is kept at rest and the other is moved very slowly in the direction of the fringes, the fringes are found to move also but at a greatly magnified rate. The number of them which pass across the field of view can readily be counted by a photocell and electronic counter. This method lends itself to very accurate and rapid measurement, for when gratings ruled with 10,000 grooves per inch are moved in this way the fringe counter will record the movement in ten thousandths of an inch. An industrial firm is collaborating with the Light Division of the N.P.L. in applying this method to the control of machine tools, such as jig borers, and is working out a further application of it to the automatic control of machines. When this work is completed it will be possible for elaborate machining operations to be performed from instructions stored up in a tape machine.

Personal and Business

MONKS AND CRANE, Ltd., Birmingham, has moved its Manchester office to 8, Wilmslow Road, Manchester, 14.

MR. T. R. HAWTHORN, A.C.G.I., has been appointed resident representative in Colombia of the General Electric Company, Ltd.

MR. S. T. CLAYTON has been appointed motive power superintendent at Euston, in the London Midland Region of British Railways.

MR. R. IAN DOUGLAS has been appointed technical representative (railway engineering) of Permali, Ltd., 54, Victoria Street, London, S.W.1.

JOHNSON AND PHILLIPS, Ltd., Charlton, London, S.E.7, states that Mr. F. J. Aldridge is now in charge of its cable test and research department.

THE ENGLISH ELECTRIC COMPANY, Ltd., announces the appointment of Mr. P. J. Daglish, A.M.I.E.E., as manager of its aircraft equipment division at Bradford.

MR. STANLEY BARR has retired from the position of general manager of the Union-Castle Mail Steamship Company, Ltd., after completing fifty years in the company's service.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., announces the appointment of Mr. E. R. Smith, A.M.I.E.E., as manager of its new cable factory at Wadeville, near Johannesburg.

G.W.B. FURNACES, Ltd., Dudley, announces that it has acquired the sole licence for the British Commonwealth to manufacture and supply the control gear developed by Officine Meccaniche Riunite, Milan.

HOOVER, Ltd., announces the following appointments : Mr. J. C. Shapley, chief production engineer, Perivale ; Mr. E. E. Baldwin, works manager, High Wycombe factory ; Mr. E. Bennett, production manager, and Mr. J. T. King, production engineer, at the Cambuslang factory.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., states that Mr. S. G. Turner has been appointed superintendent, lamp and lighting department, London, in succession to Mr. F. N. Woods. Mr. J. J. Berry has been appointed superintendent, lamp and lighting department, Cardiff.

JAMES NEILL AND CO. (SHEFFIELD), Ltd., Napier Street, Sheffield, states that it has acquired the whole of the issued share capital of Hallamshire Steel and File Company, Ltd. It is stated that this acquisition will not lead to any change in the existing management of the latter company.

MR. B. H. DULANTY and Mr. I. M. Gillett, chairman and managing director respectively of Silentbloc, Ltd., have been appointed directors of the Andre Rubber Company, Ltd. Mr. H. Clements has been appointed joint managing director of the Andre Rubber Company, Ltd., and a director of Silentbloc, Ltd.

British Patent Specifications

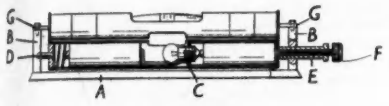
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

TOOLS AND WORKSHOP APPLIANCES

702,492. September 12, 1951.—SPIRIT LEVELS, Walter Francis Hoskins, 30, Andrew Street, West Hartlepool.

The object of the invention is to provide a short form of level which uses the standard batteries for illumination and provides an "engineer's" all-metal spirit level. In the spirit level a metal base-plate *A* has its under side finished with a plane surface for resting on the face to be levelled. At each end of the base-plate is a vertical pillar *B*. Between these pillars is held a battery and lamp casing *C*, the closed end of the casing having an axial spigot *D* to engage in a corresponding recess formed up the inside of the left-hand pillar *B* at a height to leave a slight clearance between the casing



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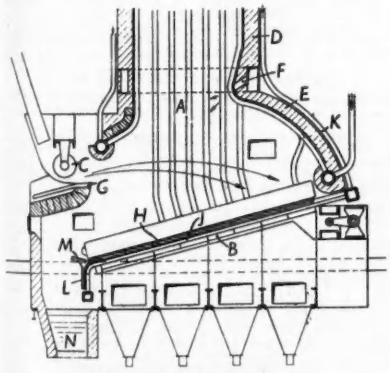
and the base. In the right-hand pillar *B* there is formed a threaded bore in engagement with which is a knurled headed sleeve *E* with its inner end against the battery casing *C*. The end of the battery casing adjacent this sleeve has inserted in it a closed tube containing the battery lamp and the screw switch *F*. On the upper ends of the pillars *B* a cylindrical spirit level is mounted by means of horizontal eye lugs *G* projecting from the ends of the level casing. The cover sleeve of the level has formed diametrically opposite the spirit level a light admission opening which registers with an opening in the battery casing. A wooden spirit level and a torpedo form of spirit level are also shown in the specification.—*January* 20, 1954.

STEAM GENERATORS

703,200. September 28, 1951.—STOKING ARRANGEMENT FOR STEAM-GENERATING INSTALLATIONS, L. and C. Steinmüller G.m.b.H., Gummersbach/Rhineland, Germany.

The invention relates to a stoking arrangement, particularly for steam-generating installations, in which the fuel is projected into the fire chamber. Referring to the drawing, the combustion chamber *A* of a water-tube boiler contains a vibrating grate *B* on to which the fuel is thrown by a projection-charging device *C*, as indicated by the curved arrows. The lower portion of the rear wall *D* of the chamber is formed as a hanging cover *E*. It may, however, extend vertically or approximately vertically. At the angle of the rear wall, or with a straight vertical wall, at a corresponding height above the grate, secondary air nozzles *F* are distributed across the width of the chamber. For assisting the projection



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of the fuel, air may be introduced through nozzles *G*, underneath the charging device *C*. The grate is furnished with a water-cooled covering *H* with a cooling pipe system *J* connected to the boiler water circulation through pipes *K*. The front end of the grate *B* is constructed as a comparatively long damming or holding-up plate *L* having a surface *M* with a slight inclination opposite to that of the plane of the grate, so that the cinders accumulating at the surface *M* tend to receive a motion directed oppositely to that of the fuel bed. This produces a damming effect. The inclination of the surface may be made adjustable, if desired. The cinders falling away over the plate *L* accumulate in a collecting space *N* located near the stoker's position and can be discharged.—*January* 27, 1954.

MARINE ENGINEERING

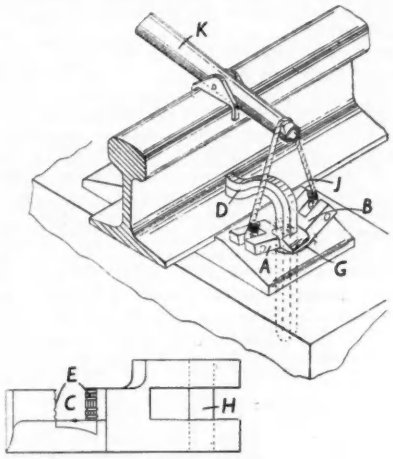
703,158. March 1, 1950.—PREVENTING OR MINIMISING THE FOULING OF SHIPS' HULLS BY MARINE GROWTHS, Postans, Ltd., Trevor Street, Birmingham 7, and Clarence Owen Morley, of the company's address.

The invention has reference to a method of preventing or minimising the fouling of ships' hulls by marine growths and organisms. The invention is put into practice by causing the submersible portion of a ship's hull to vibrate at ultrasonic frequencies under the influence of a number of transducers of the magneto-striction type which are in contact with the inner surface of the submersible portion of the hull at spaced intervals. It is known that organic growths are vulnerable to vibrations in the ultrasonic frequencies and are reluctant to settle on an unsuitable surface, and hence by causing ships' hulls to vibrate at ultrasonic frequencies fouling is prevented or minimised.—*January* 27, 1954.

RAILWAY ENGINEERING

703,146. September 25, 1952.—EXTRACTOR FOR RAIL SPIKES, Edward Hales Tustain, Vandon Court, Petty France, Westminster, S.W.1, and Bernard Llewellyn Middleton, 240, Chase Side, Southgate, N.14.

The invention concerns a device for withdrawing rail spikes and has for its object to provide an extractor which will extract broken spikes provided at least 1in of broken spike projects above the base plate. As shown in the drawings, the device comprises a pair of loosely interfitting rail spike gripping members *A* and *B* shaped to lie adjacent one another and each provided with an open jaw *C* to engage the spike *D*. The opposite walls *E* of each open jaw are inclined and are provided with knurled surfaces to grip the spike. The base is preferably bevelled



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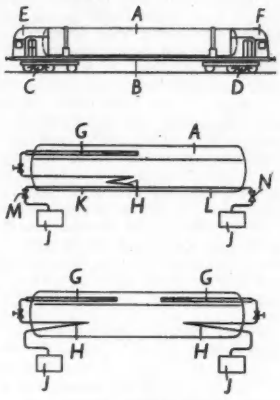
as indicated at *G* so that when the members are tilted the bevelled surfaces may bear on the base plate of the rail. The remote end of each gripping member is forked and provided with a transverse pin *H* forming an anchorage for a cable *J*. To withdraw a rail spike the gripping members are placed about the spike as shown and a lever *K* fulcrumed on the rail is placed in the bight of the cable and pressure applied to the other end of the lever. In the particular arrangement illustrated there is pivoted to the lever a saddle piece to embrace the rail, while a projection on the lever serves to hold the cable. Pressure on the lever tilts the gripping members equally, causing the surfaces *E* of each jaw to bite into the spike. On completion of the extraction of the spike the gripping members fall apart and the device is ready for re-use.—*January* 27, 1954.

703,311. October 9, 1952.—STEAM ACCUMULATOR RAIL VEHICLES, Henschel and Sohn, G.m.b.H., 2, Henschelstrasse, Kassel, Germany. (*Inventor: Paul Gilli.*)

Referring to the upper view a steam accumulator *A* is mounted on longitudinal girders *B* on bogies *C* and *D*. The girders *B* are made so long that driving positions *E* and *F* can be set up at front and at rear of the accumulator. Steam drawing-off tubes *G* shown in the two lower views, and accordingly one or two superheaters *H*, are built into the accumulator *A* at one or at both ends. The superheated steam from the accumulator is fed to the driving engines *J* through pipes *K* and *L*, if desired by way of the hollow pivot pins of the bogies *C* and *D*. The steam drawing-off valves *M* and *N* can be operated individually, or can be coupled with one another, so that it is possible at



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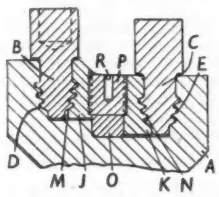
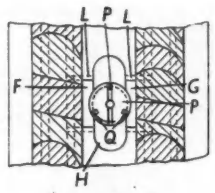
any time to drive with the engine or engines of one or both of the bogies. Exhaust steam from the engines can be used for the direct or indirect heating of the train.—*February* 3, 1954.

TURBINES AND COMPRESSORS

703,173. February 7, 1951.—SECURING BLADING TO TURBINE WHEELS, W. H. Allen, Sons and Co., Ltd., and Claude Warren Hayes, of the company's address at Queens Engineering Works, Bedford.

The invention relates to means for securing blading to turbine wheels and other high speed rotary members by the use of an undercut circumferential groove in the rim of the wheel into which are fitted the root portions of the blading element through a gap. In the drawing the circumferential grooves in the wheel rim *A* which receive the blade roots *B* and *C* are provided with the usual lateral undercut formations *D* and *E*, having a series of serrations. The inner side walls of the adjacent grooves are provided with one or more gates *F* and *G* through which the blade roots can be assembled in the grooves. The opposite gates communicate with a parallel sided recess *H* in the wheel rim lying between the two rows of blades and extending circumferentially beyond the gates in both directions. This recess has rounded ends and its depth is preferably the





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same as that of the blading grooves. Gate closing pieces *J* and *K* are provided and their sides are serrated or grooved to mate with the gate sides *L*. The ends *M* and *N* of the closing pieces which face the wheel grooves are also serrated to form continuations of the lateral serrated formation of the wheel grooves. The length of each closing piece is such that when inserted into the gate and engaged with the root portion of a blade, the rear end of the closing piece is aligned with the side of the recess. The packing piece *O* is formed with rounded ends and completely fills the recess, so that the two gate closing pieces are simultaneously held in position. To retain the packing piece in its recess against radial forces, a radial hole is drilled in its centre to overlap the ends of the two closing pieces and a threaded plug *P* is screwed into the hole. To prevent loosening of the retaining plug, one or more longitudinal slots *Q* are formed and a part of the material of the packing piece is forced into such slots by punching. The plug is provided with a slot *R* in its upper end to enable it to be driven into the threaded hole or removed from it.—*January* 27, 1954.

Books of Reference

Kempe's Engineer's Year-Book. 59th Edition. London: Morgan Brothers (Publishers), Ltd., 28, Essex Street, W.C.2. Price 75s. (77s. 6d. post free).—This well-known reference book appears this year in the same red cover and same size, crown octavo, as usual and again, as usual, it is divided into two volumes within a stiff cardboard cover. Within the covers, however, there has been much change. Indeed, this 1954 edition can almost be said to be an entirely new work. For every chapter has been either completely re-written or so substantially re-written as to be in effect new. There are also a number of new chapters over and above those that have appeared in previous issues. They include chapters on Atomic Power, Fundamentals of Electrical Engineering, Industrial Safety and Protection, Mechanical Handling, Plastics, Powder Metallurgy, and Theory of Structures. We note that there has, too, been some rearrangement and grouping of allied subjects; and that, no doubt in consequence of the addition of new material, certain familiar headings have disappeared and been replaced by others. For example, the chapter once headed Metallurgy has now been divided into three headed Iron and Steel, Non-Ferrous Metals and Alloys, and Foundry Practice, respectively. Properties, Weights and Strength of Materials, once a single chapter, similarly has been divided into Standard Dimension and Engineering Materials, a chapter to each. Again the heading Aircraft and Aero-Engines no longer appears. Instead there are chapters on Aerodynamics and Aircraft Propulsion. There are also certain other new headings, such as Electronic Engineering, Flow Metering and Mechanical Testing, and Road Vehicles, that have not appeared before. As if this very complete revision of the work were not enough, the volume has also been reset in a new and clearer type face; and there are over 1500 new illustrations. Altogether there are some 3000 pages, divided between the two volumes, which contain in all seventy-nine chapters, each contributed and arranged by an authority on the subject concerned. The editing, as the preface reveals, has been done by Mr. C. E. Prockter, M.I.E.E., M.I.Mech.E., under the general direction of the Editor-in-Chief of this journal.

The heart of any reference book such as Kempe's lies in its index. The index, like the work as a whole, has been completely reset. It now takes up 125 pages contains 17,000 entries and provides a fully cross-referenced guide to the contents. Though it is astonishing how much information can be, and is, packed into this Year-Book, it is obviously also desirable that those who use it should be guided to sources of further information, if required. Special reference is made in all sections of the work to British Standards; and most of the chapters include a selected bibliography.

Kempe's has always been remarkable for the wealth of information useful to engineers of all kinds contained within its relatively small volumes. Maybe, since the present edition, like others for many years past, was produced under our editor's direction, we are biassed. But this, the 59th Edition, seems to us to surpass all previous editions in value.

Launches and Trial Trips

HERTHA, oil tanker; built by the Blythswood Shipbuilding Company, Ltd., for the Skibsaktieselskapet William Hansen Rederi, Bergen; length 305ft, breadth 44ft, depth 20ft 3in, deadweight 3500 tons on 18ft 6in draught; ten cargo oil tanks, one pump room, two 200 tons per hour steam driven cargo oil pumps, trial speed in load condition 11·5 knots; triple expansion steam engine, two Scotch boilers, provide steam at 220 lb per square inch and 580 deg. Fah. Trial, February 11th.

TEMPLE HALL, cargo ship; built by The Caledon Shipbuilding and Engineering Company, Ltd., for the Temple Steamship Company, Ltd.; length between perpendiculars 425ft, breadth moulded 58ft 6in, depth to shelter deck 37ft 9in, deadweight 10,400 tons on 26ft 11¼in draught, service speed 12 knots; five cargo holds, ten 10-ton and one 30-ton derricks, electrical deck machinery; two Cochran boilers, three 200kW diesel-driven generators; Vickers-Doxford oil engine, 3300 b.h.p. at 108 r.p.m. Trial, February 12th.

PERSIAN GULF, oil tanker; built by the Chantier et Ateliers de Saint-Nazaire-Penhoët for Afran Transport Company; length between perpendiculars 631ft, breadth moulded 86ft 9in, depth 45ft, deadweight 31,550 tons, thirty cargo oil tanks, trial loaded service speed 16·7 knots; one set of double-reduction geared turbines, 15,000 s.h.p. maximum, 13,750 s.h.p. at 105 r.p.m., two Foster-Wheeler boilers supply steam at 640 lb per square inch and 850 deg. Fah. Trials, February.

AUBY, passenger and cargo ship; built by Henry Robb, Ltd., for The Sarawak Steamship Company, Ltd.; length between perpendiculars 212ft, breadth moulded 44ft, depth moulded to upper deck 21ft, deadweight 1170 tons on 11ft 9in mean draught, service speed 10 knots; 100 unberthed passengers; two large holds; two Ruston and Hornsby supercharged, four stroke diesel engines direct-coupled to the propeller through oil-operated reverse reduction gears, 1018 total b.h.p. at 500 r.p.m.; three 75kW diesel-driven generators. Trials, February 12th.

Contracts

JOHN I. THORNYCROFT AND CO., Ltd., has been awarded the contract to convert the British Railways passenger ship "Arnhem," which is employed in the Harwich-Hook of Holland service, from a one-class ship to one carrying first and second-class passengers.

THE POWER-GAS CORPORATION, Ltd., Stockton-on-Tees, announces that its Australian subsidiary has secured a contract, worth about £1,000,000, from Petroleum and Chemical Corporation (Australia), Ltd., Sydney, for the construction of chemical plant. This contract includes the design, manufacture and installation of a plant to make high-grade town gas from heavy petroleum oil, along with the recovery of valuable by-products.

THE GOVERNMENT OF IRAQ DEVELOPMENT BOARD has accepted the tender of Dorman, Long and Co., Ltd., Middlesbrough, for the construction of a new road bridge in Iraq over the River Euphrates. The value of the contract is £350,000. The site of the bridge is at Hindiya, 65 miles south of Baghdad. The bridge will be 570ft long and 46ft wide, and will have a steel central span with reinforced concrete approaches. The piers will be of steel piled construction. The total weight of steelwork is 1500 tons and the bridge is to be completed within 18 months from the beginning of construction. The consulting engineers are Messrs. Maunsell, Posford and Pavry.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases, the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., March 11th.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, "The Acoustic Design and Measurement of Buildings," H. C. Watson, 7 p.m.——N.W. SECTION: College of Technology, Sackville Street, Manchester, 1, "Colour Television," G. B. Townsend, 7 p.m.
Fri., March 12th.—SCOTTISH SECTION: The University, Edinburgh, "The Acoustic Design and Measurement of Buildings," H. C. Watson, 7 p.m.

DIESEL ENGINE USERS ASSOCIATION

Thurs., March 18th.—Caxton Hall, Westminster, London, S.W.1, "Preventive Maintenance from Breakdown Experience," H. D. Adam, 2.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., March 8th.—DUNDEE BRANCH: Mathers Hotel, Dundee, Annual General Meeting, 7.30 p.m.
Tues., March 9th.—GLASGOW SECTION: Scottish Building Centre, 425–427, Sauchiehall Street, Glasgow, Annual General Meeting, 7 p.m.
Wed., March 10th.—E. MIDLANDS BRANCH: Demonstration Theatre, Gas Board Showrooms, Parliament Street, Nottingham, Annual General Meeting, 7 p.m.——EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, Annual General Meeting, 7 p.m.
Thurs., March 11th.—N.E. BRANCH: Roadway House, Oxford Street, Newcastle upon Tyne, Annual General Meeting, 7 p.m.——SHEFFIELD AND DISTRICT BRANCH: Grand Hotel, Sheffield, General Discussion on "Maintenance Problems," 7.30 p.m.
Fri., March 12th.—BIRMINGHAM BRANCH: Imperial Hotel, Birmingham, Contractors' Plant Discussion Group, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., March 6th.—LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, "Inter-Relation of Combustion and Metallurgical Reactions in the Cupola," D. Fleming, 3 p.m.
Thurs., March 11th.—LINCOLNSHIRE BRANCH: Technical College, Lincoln, "Mechanical Aids to Production," H. Hadan, 7.15 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., March 9th.—85, Minories, London, E.C.3, "Heat Exchangers for Marine Oil Engines," H. E. Upton, 5.30 p.m.

INSTITUTE OF METALS

Mon., March 8th.—SCOTTISH LOCAL SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Powder Metallurgy," D. D. Howat, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., March 10th.—Manson House, 26, Portland Place, London, W.1, "Surface Failure in Gears," A. Cameron, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., March 10th.—E. MIDLANDS CENTRE: Mechanics Institute, Nottingham, "Air Pressure Brakes and Auxiliaries for Road Vehicles," W. A. Kirk, 7.30 p.m.

INSTITUTE OF TRANSPORT

Mon., March 8th.—Jarvis Hall, 66, Portland Place, London, W.1, "Continental Traffic: A Look Forward," L. H. K. Neil, 5.45 p.m.

INSTITUTE OF WELDING

Thurs., March 11th.—S. LONDON BRANCH: 2, Savoy Hill, London, W.C.2, "Welding of Stainless Steel Vessels," J. F. Lancaster, 6.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., March 9th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The Development of Spraying Machines in this Country and Overseas and Methods of Assessing Their Performance," E. R. Hoare, 2.15 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., March 10th.—MIDLANDS BRANCH: The University, Edmund Street, Birmingham, "Design of Pressure Vessels and the Mechanism of Failure in Service," A. H. Goodger, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, March 5th.—N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "Design of Foundations in Relation to Superficial Geological Deposits in the North-West Area," B. M. Evans, 6.30 p.m.
Tues., March 9th.—STRUCTURAL AND BUILDING MEETING: Great George Street, Westminster, London, S.W.1, "Design and Construction of a Prestressed Concrete Framed Transit Shed for the Port of London Authority," N. N. B. Ordman and I. S. S. Greeves, 5.30 p.m.
Thurs., March 11th.—MIDLANDS ASSOCIATION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Highway Construction Plant," R. R. W. Grigson, 6 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., March 8th.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "How Can Electrical Methods Enhance Industrial Productivity," opened by Sir Henry Clay, 5.30 p.m.
Wed., March 10th.—RADIO SECTION: Savoy Place, London, W.C.2, "A Study of Some of the Properties of Matter Affecting Valve Reliability," E. A. O'Donnell Roberts, 5.30 p.m.——N. SCOTLAND SUB-CENTRE: Caledonian Hotel, Aberdeen, "Economic Aspects of Overhead Equipment for D.C. Railway Electrification," O. J. Crompton and G. A. Wallace, 7.30 p.m.
Thurs., March 11th.—EXTRA MEETING: Savoy Place, London, W.C.2, "An 8 MeV Linear Accelerator for X-Ray Therapy," C. W. Miller, 5.30 p.m.——N. SCOTLAND SUB-CENTRE: Royal Hotel, Dundee, "Economic Aspects of Overhead Equipment for D.C. Railway Electrification," O. J. Crompton and G. A. Wallace, 7 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Wed., March 10th.—WOLVERHAMPTON BRANCH: Compton Grange, Compton Road, Wolverhampton, "Engineering Applications of Electro-Deposited Metals," J. W. Oswald, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., March 9th.—39, Elmbank Crescent, Glasgow, "Ships' Lifts," J. Austwick and S. T. Elvy, 6.45 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Thurs., March 11th.—Visit to Cambridge University, Engineering Department, and Tour of the Colleges, Train leaving Liverpool Street Station, 9.47 a.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 5th.—N.E., A.D. GRADUATES' SECTION: Gas Board Showrooms, 30, Grainger Street, Newcastle upon Tyne, Annual General Meeting, "Some Notes on Cranes," W. I. O. Moffat, 7 p.m.
Tues., March 9th.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, "Automobiles on Alpine Passes," Max Troesch, 5.30 p.m.
Thurs., March 11th.—N.W. BRANCH: Engineers' Club, Albert Square, Manchester, Presidential Address, A. Roebuck, 6.45 p.m.
Fri., March 12th.—GROUP DISCUSSION: 1, Birdcage Walk, Westminster, London, S.W.1, Industrial Administration and Engineering Production Group, "The Productivity Report on Design for Production," 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., March 9th.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The Theory and Application of Transistors," F. F. Roberts and H. G. Bassett, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., March 8th.—SHEFFIELD SECTION: Grand Hotel, Sheffield, "Work Measurement," T. U. Matthew, Annual General Meeting, 6.30 p.m.——YORKSHIRE SECTION: Hotel Metropole, Leeds, 1, Annual General Meeting, "Education and the Production Engineer," R. Shilton, 7.30 p.m.
Wed., March 10th.—LONDON GRADUATE SECTION: 36, Portman Square, London, W.1, Annual General Meeting and Film Evening, 7.15 p.m.——PRESTON SECTION: Crown Hotel, Blackburn, "Some Thoughts on the Works Study Approach to Productivity," E. H. Shaw, 7.15 p.m.——WESTERN SECTION: Grand Hotel, Broad Street, Bristol, Annual General Meeting, 7 p.m.——"Spark Machining," G. Fefer, 7.30 p.m.——WOLVERHAMPTON SECTION: Technical College, Wolverhampton, "Fuel and Energy Conservation," W. L. Boon, Annual General Meeting, 6.30 p.m.
Thurs., March 11th.—LEICESTER SECTION: Bell Hotel, Leicester, "Standard Costs and Budgetary Control as an Aid to Management," H. Senior, 7 p.m.——LONDON SECTION: Royal Empire Society, Northumberland Avenue, London, W.C.2, "Building of Large Turbo-Alternators," J. R. Cotterill, 7 p.m.
Fri., March 12th.—EASTERN COUNTIES SECTION: Diocesan Hall, Tower Street, Ipswich, Annual General Meeting, "A Machine Tool Symposium," 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 5th.—Townsend House, Greycoat Place, London, S.W.1, Film Evening, 7 p.m.
Mon., March 8th.—N.W. SECTION: Engineers' Club, Albert Square, Manchester, Election of Officers, Film Evening, 7.30 p.m.——SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, Sheffield, "The Use of High-Frequency Heating in the Metallurgical Industry," J. B. Ingall, 7.30 p.m.
Fri., March 12th.—ORDINARY MEETING: Townsend House, Greycoat Place, London, S.W.1, "General Principles of Boiler Water Treatment," W. F. Gerrard, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., March 10th.—24, Dale Street, Liverpool, "The Use of Aluminium for Structural Purposes," D. U. Pike, 6 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., March 11th.—Liverpool Engineering Society, 24, Dale Street, Liverpool, "Titanium: A Metal of Engineering Importance," P. L. Teed, 7 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., March 12th.—Mining Institute, Newcastle upon Tyne, "Marine Shafting Alignment," G. Yellowley and J. E. Richards, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Wed., March 10th.—LOUIS BLERIOT LECTURE: Salle des Anciens Eleves des Ecoles d'Arts et Metiers, 9, bis avenue d'Ilena, Paris, "The Domain of the Helicopter," R. Hafner, 5 p.m.——GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, Annual General Meeting and Film Show, 7.30 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Thurs., March 11th.—GENERAL MEETING OF LAND SURVEYORS: 12, Great George Street, Westminster, London, S.W.1, "Hydrographic Surveys: The Purpose and the Choice of Scale," A. Day, 5.30 p.m.

ROYAL SOCIETY OF ARTS

Wed., March 10th.—THOMAS GRAY MEMORIAL LECTURE: John Adam Street, Adelphi, London, W.C.2, "Safety in Ships," J. P. Thomson, 2.30 p.m.

WOMEN'S ENGINEERING SOCIETY

Wed., March 10th.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Air Transport," Philip Kidson, 6.45 p.m.